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Final Report of the Fisheries Oceanography Committee 2007 Annual Meeting

3-5 April 2007

Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Michael Sinclair (Chairperson)

Fisheries and Oceans Canada
Maritimes Region
Bedford Institute of Oceanography
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January 2008

Rapport final de la réunion annuelle 2007 du Comité océanographique des pêches

du 3 au 5 avril 2007

Institut océanographique de Bedford
Dartmouth (Nouvelle-Écosse)

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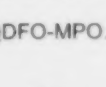

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SUMMARY

The Fisheries Oceanography Committee (FOC) of the Department of Fisheries and Oceans (DFO) met at the Bedford Institute of Oceanography (Dartmouth, Nova Scotia) from April 3 to 5, 2007. The focus of the 2007 meeting was to evaluate different measures of condition of diverse species (fish, invertebrates, mammals, and seabirds) with the aim of agreeing on some common indices that would subsequently be used in comparative analyses among groups. An additional issue was to consider a template for regional and zonal "Ecosystem Status" reporting in support of the "Ecosystem Approach".

A proposed template for a report that would address the degree to which the managed human activities are a contribution to the observed changes in ecosystem properties was presented. Such a report was expected to address the degree to which the conservation objectives for an oceans management area (e.g. a Large Ocean Management Area [LOMA]) are being met, including cumulative impacts of each sector (e.g. fishing) and across sectors (e.g. fishing, aquaculture, oil/gas, marine transportation). While interested in general terms, the participants did not wish to address the management aspects of reporting, but rather to identify relevant contextual indicators that track changes in ecosystem structure and function.

The Committee discussed the needs for indicators of oceanographic properties to interpret changes in ecological characteristics of species at higher levels of the food chain. It is the expectation that the Atlantic Zone Monitoring Program (AZMP) will provide this category of information. To accomplish the synthesis of zonal trends in ecosystem status for the northwest Atlantic, it was proposed that a joint meeting with AZMP in 2008 would be desirable.

Trends in condition for fish species were presented for the southern Gulf of St. Lawrence (sGSL), the northern Gulf of St. Lawrence (nGSL), the Grand Banks and southern Labrador Shelf, and the Scotian Shelf. In addition, trends in the condition of scallops, herring, capelin, seabirds, and marine mammals were provided for selected areas. Different methods were used in different regions.

For the southern Gulf of St. Lawrence, fish condition has varied considerably within and among species during the 1971 to 2006 time period. However, the fish community as a whole has not shown the directional trends in condition that have been observed on the eastern Scotian Shelf. In general, the condition of smaller-bodied species has decreased since the early 1990s. This is coincident with large increases in the biomass of most small-bodied fish species, suggesting possible density-dependent competitive effects.

For the northern Gulf of St. Lawrence, condition indices were estimated for Atlantic cod for 1984 to 2006. The pattern observed over time is complex. Since 1995, there has been an increase in condition factors; and the 2000 to 2006 levels are comparable to the high levels observed in the 1984 to 1985 period. No trend in condition has been observed for Greenland halibut for the 1995 to 2006 period. Trends for herring, mackerel (southern Gulf), and shrimp were also summarized. Overall, the preliminary analyses, and summary from the published literature, suggest that the early 1990s were years of relatively poor growth and low condition for many species in the northern Gulf of St. Lawrence. The positive trends since the mid 1990s suggest that ecological conditions have been improving in this geographic area.

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenus dans le présent rapport puissent être inexacts ou propres à induire en erreur, ils sont quand même reproduits aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considéré en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

For cod on the southern Labrador Shelf to the Grand Banks, it was noted that different methods show contradictory trends. A synthesis is under way, but general conclusions have not yet been made. For the fish community as a whole on the Labrador Shelf and Grand Banks, it was concluded that there have been changes in condition during the 1990 to 2004 period. There is a latitudinal pattern, with more evident changes in the Northwest Atlantic Fisheries Organization (NAFO) divisions 2J and 3NO areas. There has been no consistent temporal pattern among species, with, for example, capelin and herring in Div. 3K showing opposite trends as described for plaice and witch in Div. 2J.

On the Scotian Shelf, a comparison was made between temporal trends in condition for 4 trophic groups (piscivores, large benthivores, medium-sized benthivores, and pelagic predators) in divs. 4VW and 4X for the 1970 to 2006 time period. In general, aggregated condition was lower in the later period in all groups in both areas. Analyses on the causes in the trends (fishing, bottom temperature, and population biomass) did not infer strong causal relationships for a particular parameter. A detailed study on Scotian Shelf haddock (4VW) growth was presented. It was argued that size-selective fishing is the most parsimonious explanation for the systematic declines in size-at-age and age-at-maturity for this haddock stock.

Studies on trends in condition for pelagic fish in Newfoundland waters was presented. Complex spatial and temporal patterns in condition were described for diverse populations. Common to all of the 4 areas studied was a decrease in condition in the early 1990s. A 2nd study on herring in Newfoundland waters addressed environmental and evolutionary influences on maturation during the 1983 to 2005 period. Age and size at maturation declined through time. Also, growth rates decreased at the same time. Given the preliminary nature of the study, general conclusions are yet to be made. For capelin, the analyses presented indicated that the long-term decline starting in the early 1990s has been reversed during the last several years. That said, different geographic areas show different, and sometimes ambiguous, temporal patterns.

For seabirds, only 1 species (Atlantic puffin) was addressed. The analysis indicates that there has been a positive trend in condition between 1991 and 2004, with recent values comparable to the high estimates in the early 1980s.

A detailed analysis of trends in condition of harp and hooded seals in the northern Gulf of St. Lawrence was presented. The results indicate that condition and growth were significantly reduced during the 1990s compared to the earlier period. It is suggested that density-dependent effects have been influential, with both seal species having more difficulty feeding effectively during the 1990s than during the 1980s.

A final condition study was presented for sea scallops in the Bay of Fundy. Both spatial and temporal patterns in condition were described. At this stage, the causes of the differences have not been determined.

A summary of the spatial and temporal coverage of diverse oceanographic properties was provided for the shelf seas in the northwest Atlantic from Labrador Shelf to the Gulf of Maine. It was concluded that the data set is relatively rich for both hydrographic and plankton indices.

The general discussion generated the next steps, including a workshop to be held in Moncton, New Brunswick, from February 5 to 8, 2008. The goals of the proposed workshop are to agree on a basic set of common analyses that would be included in the various regional Ecosystem Status Reports (ESRs), and to standardize/homogenize to some degree these analyses. Choosing criteria for classifying species by functional group, and deciding on which measures of

condition should be used, are examples of "standardization/homogenization". H. Benoît agreed to chair this workshop. It was also proposed that a joint session be held with AZMP during the week of March 16, 2008, in Montreal, Quebec. The goal of the joint session would be to discuss the oceanographic indices that would be most useful in the interpretation of trends in ecological and ecosystem properties at higher trophic levels.

SOMMAIRE

Le Comité océanographique des pêches (COP) du ministère des Pêches et des Océans (MPO) s'est réuni à l'Institut océanographique de Bedford (à Dartmouth, en Nouvelle-Écosse) du 3 au 5 avril 2007. Cette réunion visait principalement à évaluer différentes mesures de la condition d'espèces diverses (poissons, invertébrés, mammifères et oiseaux de mer), dans le but d'en arriver à des indices communs qui pourraient être utilisés par la suite pour effectuer des analyses comparatives entre groupes. Il était prévu aussi de discuter d'un modèle de rapport sur l'« état de l'écosystème », à l'appui de l'« approche écosystémique ».

Un modèle de rapport reflétant le degré de contribution des activités anthropiques gérées aux changements observés dans les caractéristiques de l'écosystème a été présenté. Il devait permettre de déterminer dans quelle mesure les objectifs de conservation établis pour telle ou telle zone de gestion des océans (p. ex. une zone étendue de gestion des océans [ZEGO]) ont été atteints et de déterminer aussi les incidences cumulées de chaque secteur d'activité (p. ex. la pêche) et des divers secteurs combinés (p. ex., la pêche, l'aquaculture, l'industrie pétrolière et gazière et le transport maritime). Bien que le sujet ait intéressé en général les participants, ceux-ci ne souhaitaient pas aborder l'aspect administratif des rapports, mais désiraient plutôt établir des indicateurs contextuels pertinents, qui permettraient de surveiller les changements survenant dans la structure et la fonction de l'écosystème.

Le Comité a discuté de la nécessité de disposer d'indicateurs des caractéristiques de l'océan pour interpréter les changements dans les caractéristiques écologiques des espèces aux niveaux supérieurs de la chaîne trophique. On s'attend à ce que le Programme de monitorage de la zone atlantique (PMZA) fournisse ce genre d'information. Pour effectuer la synthèse des tendances de l'écosystème de l'Atlantique Nord-Ouest à l'échelle de la zone, une réunion conjointe avec les responsables du PMZA en 2008 a été jugée souhaitable.

Les participants à la réunion ont pu prendre connaissance des tendances de la condition de diverses espèces de poisson dans le sud et dans le nord du golfe du Saint-Laurent, sur les Grands Bancs et dans le sud du plateau continental du Labrador ainsi que sur le plateau néo-écossais. On leur a aussi présenté les tendances de la condition des pétoncles, du hareng, du capelan, des oiseaux de mer et des mammifères marins dans des zones données. Les analyses faisaient appel à des méthodes qui différaient selon les régions.

Dans le sud du golfe du Saint-Laurent, la condition du poisson a varié considérablement parmi les espèces de 1971 à 2006. Toutefois, on n'a pas observé au sein des populations de poisson dans leur ensemble les tendances directionnelles constatées dans l'est du plateau néo-écossais. En général, la condition des poissons de petite taille a diminué depuis le début des années 1990. Cela coïncide avec les fortes hausses de la biomasse de la plupart de ces poissons, ce qui laisse croire à des phénomènes de concurrence dus à la densité.

Dans le nord du golfe du Saint-Laurent, des indices de la condition de la morue ont été estimés pour la période 1984-2006. La tendance observée au fil du temps est complexe. Depuis 1995, une amélioration de la condition a été observée et les résultats de 2000 à 2006 sont comparables aux pics observés en 1984 et 1985. Pour ce qui est du flétan noir, aucune tendance de la condition ne se dégageait dans la période 1995-2006. Des synthèses des tendances de l'évolution de la condition du hareng, du maquereau (du sud du Golfe) et de la crevette ont aussi été présentées. Selon l'ensemble des analyses préliminaires et le résumé

des documents publiés, le début de la décennie 1990 aurait été une période de croissance relativement faible et de piètre condition pour de nombreuses espèces du nord du golfe du Saint-Laurent. Les tendances positives observées depuis le milieu des années 1990 portent à croire que les conditions écologiques se sont améliorées dans cette région.

S'agissant de la morue des eaux qui vont du sud du plateau continental du Labrador aux Grands Bancs, on a constaté que des méthodes différentes produisent des tendances contradictoires. Une synthèse est en cours, mais on n'en a pas encore tiré de conclusions générales. En ce qui concerne l'ensemble des populations de poisson du plateau continental du Labrador et des Grands Bancs, il a été établi que des changements dans la condition s'étaient produits de 1990 à 2004. Il se dégage une tendance latitudinale, reflétant des changements plus marqués dans les divisions 2J et 3NO. Il n'y a pas eu de tendances temporelles cohérentes entre les espèces; ainsi, le capelan et le hareng de 3K présentent des tendances opposées à celles de la plie canadienne et de la plie grise de 2J.

Sur le plateau néo-écossais, on a comparé les tendances temporelles de la condition chez quatre groupes trophiques (les piscivores, les grands benthivores, les benthivores de taille moyenne et les prédateurs pélagiques) de 4VW et 4X de 1970 à 2006. En général, la condition globale était plus basse dans la fin de la période, cela pour tous les groupes et dans les deux divisions. Les analyses des causes des tendances (pêche, température du fond et biomasse de la population) ne révélaient pas de forte relation particulière de cause à effet. Une étude détaillée portant sur l'aiglefin du plateau néo-écossais (4VW) a été présentée. Selon certains, la pêche sélective en fonction de la taille est l'explication la plus plausible des déclins systématiques de la taille selon l'âge et de l'âge à maturité dans ce stock d'aiglefin.

Des études des tendances de la condition des poissons pélagiques dans les eaux de Terre-Neuve ont aussi été présentées. Elles révélaient des tendances spatio-temporelles complexes chez diverses populations. Les quatre zones étudiées présentaient toutes une baisse de la condition au début des années 1990. Une autre étude du hareng des eaux de Terre-Neuve traitait de l'influence de l'environnement et de l'évolution sur la maturité durant la période 1983-2005. L'âge et la taille à maturité ont diminué au fil du temps. Les taux de croissance ont aussi diminué parallèlement. Étant donné le caractère préliminaire de l'étude, on n'en a encore pas tiré de conclusions générales. Pour ce qui est du capelan, les analyses présentées révélaient que le déclin à long terme amorcé au début des années 1990 s'est inversé ces quelques dernières années. Cela dit, diverses régions géographiques présentent des tendances temporelles différentes et parfois ambiguës.

Dans le cas des oiseaux de mer, on ne s'est intéressé qu'à une seule espèce, le macareux moine. L'analyse révèle une tendance positive de la condition entre 1991 et 2004, les valeurs récentes étant comparables aux hautes estimations du début des années 1980.

Une analyse détaillée des tendances de la condition du phoque du Groenland et du phoque à capuchon dans le nord du golfe du Saint-Laurent a été effectuée. Il ressort de ses résultats que la condition et la croissance ont considérablement diminué dans les années 1990 par rapport à la période antérieure. On croit que des facteurs dépendant de la densité sont entrés en ligne de compte, les deux espèces de phoque ayant éprouvé plus de difficultés à bien se nourrir dans les années 1990 que dans les années 1980.

Les participants ont également pris connaissance d'une étude finale de la condition des pétoncles géants de la baie de Fundy. Elle décrivait les tendances spatio-temporelles de la condition. Pour le moment, les causes des différences observées n'ont pas été établies.

Enfin, on a présenté un résumé des tendances spatio-temporelles de diverses caractéristiques océaniques des mers épicontinentales de l'Atlantique Nord-Ouest, depuis le plateau continental du Labrador jusqu'au golfe du Maine. L'ensemble de données sur les indices hydrographiques et sur les indices du plancton s'est avéré relativement riche.

La discussion générale a permis de cerner les prochaines phases du travail amorcé, notamment un atelier qui doit se tenir à Moncton (N.-B.) du 5 au 8 février 2008. L'atelier proposé vise à établir un consensus sur un ensemble fondamental d'analyses communes à inclure dans les divers rapports régionaux sur l'état de l'écosystème et à normaliser ou harmoniser jusqu'à un certain point ces analyses. « Normaliser ou harmoniser » c'est, par exemple, choisir les critères permettant de classer les espèces par groupe fonctionnel et décider des mesures de la condition à utiliser. H. Benoît a accepté de présider cet atelier. Il a aussi été proposé de tenir une réunion conjointe avec les responsables du PMZA dans la semaine du 16 mars 2006 à Montréal (Qc). Cette réunion servirait à discuter des indices sur les caractéristiques de l'océan qui seraient les plus utiles à l'interprétation des tendances des propriétés écologiques et écosystémiques aux plus hauts niveaux trophiques.

1.0 INTRODUCTION

The Fisheries Oceanography Committee (FOC) of the Department of Fisheries and Oceans (DFO) met at the Bedford Institute of Oceanography (Dartmouth, Nova Scotia) from April 3-5, 2007. The Terms of Reference of the committee are in Annex 1. The Chairperson (M. Sinclair) gave some opening remarks summarizing that the committee is in Year 2 of a 3-year work plan, and that the results of the 2006 activities had been well received by the Atlantic Science Directors' Committee (ASDC). It was noted that the Chairperson of the ASDC (M. Chadwick) had requested ASDC to evaluate the form of Ecosystem Status Reports (ESRs) with the aim of providing a template for the regions and the Atlantic Zone. The Co-chairperson of the meeting (K. Frank) summarized the goals of the meeting in relation to the multi-year plan. The 2006 meeting had provided summarization of data related to the composition and abundance of fish and invertebrates from each of the regions in the Atlantic Zone. The focus of the 2007 meeting is to evaluate different measures of condition of diverse species (fish, invertebrates, mammals, and seabirds) with the aim of agreeing upon some common indices that would subsequently be used in comparative analyses amongst regions. The Agenda (Annex 2) was outlined, and accepted as presented.

2.0 FOC CORE MEMBERSHIP AND PARTICIPATION

Whilst participation in the activities of FOC is open to all, the committee formally consists of a number of core members whose responsibilities are to disseminate information to their respective laboratories and to provide a leadership role within the committee. At the time of the 2007 annual meeting, the FOC core members are:

- Eugene Colbourne[1] - Northwest Atlantic Fisheries Centre
- Mariano Koen-Alonso - Northwest Atlantic Fisheries Centre
- Fran Mowbray - Northwest Atlantic Fisheries Centre
- Claude Savenkoff - Institut Maurice-Lamontagne
- Jacques Gagné[1] - Institut Maurice-Lamontagne
- Patrick Ouellet - Institut Maurice-Lamontagne
- Hugues Benoît - Gulf Fisheries Centre
- Joel Chassé - Gulf Fisheries Centre/Bedford Institute of Oceanography
- Doug Swain[1] - Gulf Fisheries Centre
- Robert Branton - Bedford Institute of Oceanography
- Ken Frank - Bedford Institute of Oceanography
- Brian Petrie - Bedford Institute of Oceanography
- Don Clark[1] - St. Andrews Biological Station
- Kim Schmidt[1] - National Headquarters

The list of participants is provided in Annex 3.

[1] *Not present at the 2007 meeting.*

3.0 ECOSYSTEM STATUS REPORTS: REGIONAL NEEDS AND CONTENT

3.1 Development of a Template for Regional and Zonal "Ecosystem Status" Reporting in Support of Integrated Management under the Ecosystem Approach

M. Sinclair and R. O'Boyle presented a discussion paper on the topic of "Ecosystem Status" reporting in response to the request to FOC by M. Chadwick. The issue of geographic scale was addressed, with the need to report on management areas of different sizes (e.g. Large Ocean Management Areas [LOMAs] such as the Eastern Scotian Shelf Integrated Management [ESSIM] area and the Bras d'Or Lakes, a Coastal Management Area [CMA]). The status reports should include ecological indicators that reflect the decision-making framework of Integrated Management (IM), and thus allow comparison of the results of Canada's IM performance to be compared to relevant activities in the rest of the world. The question of frequency of reporting was posed, with the expectation that the "norm" would be every few years rather than annually. There are different approaches to reporting on the status of ecosystems. One approach is a characterization of temporal changes in the structure and function of ecosystems, such as that carried out by Choi et al. (2005) and Frank et al. (2004). This approach is useful for comparative ecosystem studies and to the interpretation of causality. An alternate approach is reporting on the status of integrated management activities for a LOMA or CMA. The reporting should allow evaluation of impact of management measures over time, as well as comparisons with other areas under IM. The report should address the degree to which the managed human activities are a contribution to the observed changes in ecosystem properties. It should address the degree to which the conservation objectives are being met, as well as cumulative impacts of each sector (e.g. fishing) and across sectors (e.g. fishing, aquaculture, oil/gas, marine transportation). The focus of the presentation was on this latter type of ESR (i.e. reporting on the status of integrated management for a LOMA or CMA).

A summary of recent developments in the practical implementation of the Ecosystem Approach to IM was provided. The approach includes:

- conservation objectives for each ecosystem component within management area;
- linked indicators and reference points for each ecosystem component by managed activities;
- management actions; and
- ESR reporting which addresses cumulative effects across sector and causality interpretations.

An outline for an ESR for ESSIM was proposed as an example. The components of the report are as follows:

- managed activities;
- status of impacted ecosystem components based on the conservation objectives;
- oceanographic and ecological properties, with focus on contextual indicators and linkages to any changes to reference points over time; and
- ecosystem health, including synthesis across managed activities.

An example of an outline for the "managed activities" component of such a report is:

- Fisheries:
  - 4VW surf clam management unit:
    - catch, bycatch, and discards, area disturbed, etc.
  - 40+ other management units

- Oil and Gas:
  - number of wells:
    - drilling mud, produced water, etc.

- Seismic surveys:
  - time, area

- Transportation industry:
  - ballast water:
    - amount and source, area dumped

- Other

The contents of the section on the indicators on status of impacted ecosystem components could be as follows:

- Productivity conservation objectives:
  - stock-specific fishing mortality, biomass change, discard catch, spawning biomass, % size, age, and sex

- Biodiversity conservation objectives:
  - incidental mortality of harvested species
  - species-at-risk recovery plan indicators
  - invasive indicators

- Habitat conservation objectives:
  - area disturbed of respective benthic community types by sector
  - contaminants from oil and gas, etc.

The section on oceanographic and ecological properties (i.e. contextual indicators) could be structured as follows:

- Circulation influences on eastern Scotian Shelf:
  - Gulf of St. Lawrence input
  - slope water (Labrador versus warmer source)

- Mixing:
  - stratification changes
  - residence time on banks

- Water mass characteristics:
  - bottom temperature by subarea
  - volume of Cold Intermediate Layer (CIL) by subarea

- Eutrophication:
  - O_2 in bottom water
  - winter nutrient concentrations
  - phytoplankton species ratios

- Plankton:
  - annual primary production by subarea
  - timing of spring bloom

  - other metrics on seasonality
  - biogeographic shifts in plankton species distributions
  - zooplankton production
  - species composition changes

- Fish:
  - biogeographic shifts
  - condition indices of selected species
  - recruitment/biomass ratios for selected species
  - natural mortality of selected species

- Marine mammals:
  - grey seal pup production
  - food consumption

A recent publication by Mathratta and Link (2006) concluded that 8 indicators on fish species captured much of the necessary information for this species group (total finfish biomass, total fisheries landings, fish planktivore biomass, fish bentivore biomass, mean individual fish length, mean individual fish weight, flatfish biomass, biomass of indicator species [e.g. longhorn sculpin)].

The ESR proposed outline ends with a synthesis section that could include:

- Definition of ecosystem health for LOMA:
  - indicators in relation to reference points
  - regime shift considerations
  - climate change impacts

- By conservation objective, a cross-sector analysis of cumulative impacts

- Comparison with other LOMAs

There was not, in general, much enthusiasm for the proposed ESR structure. The participants were more interested in the section on contextual indicators, with less interest in the sections on managed activities and conservation objectives. A discussion on the list of 8 fish indicators from the paper by Mathratta and Link (2006) led to identification of several additional papers on indicators that need consideration (Rochet and Rice 2005; Rice and Rochet 2005; Trenkel and Rochet 2003).

3.2 Close Encounters with AZMP - Report on Integration of FOC and AZMP to Produce Ecosystem Status Reports

K. Frank made a presentation based on his interaction with AZMP at their March 2007 annual meeting regarding integration of work activity conducted by FOC and AZMP. The primary reason for this interaction was to discuss the joint development of regional ecosystem status reports. At the AZMP annual meeting, K. Frank reviewed the current FOC activity in terms of its adoption in 2005 of a multi-year work plan that is intended to culminate in a series of ESRs for the various geographic areas within the northwest Atlantic. Basically, the idea is to gather data for various components necessary to describe the current and historical state of the continental shelf/inland sea ecosystems. K. Frank suggested that a way to accomplish the objective of developing regional ecosystem status reports was to hold a joint meeting in 2008 where multivariate time series compiled by AZMP and FOC would be analyzed and interpreted in a

joint manner. What follows is a brief review of the FOC multi-year plan, the response to the FOC request for a joint meeting in 2008, and a cross section of data series that AZMP is routinely compiling and updating on a regular basis.

In Year 3 (2008) of the FOC's multi-year plan, the intent is to explore inter-relationships and mechanisms that might explain the patterns revealed during the 1st 2 years of the multi-year plan. This previous activity involved a focus on quantifying temporal changes in fish species composition and abundance from research vessel (RV) survey data and the analysis of condition factors. What remains is to bring together information and analyses on the lower trophic levels, as well as ocean climate indices. It is important to discuss the most appropriate time and space scales to describe ecosystem variation at a regional scale. Thus far, FOC has used research vessel surveys at the management unit scale to define regions using annual time scales within the survey area. Multiple indices are desirable and partial redundancy is acceptable; long time series are most desirable, but the overall analysis should attempt to accommodate shorter data series.

Comments from AZMP about the proposal for a joint meeting were as follows:

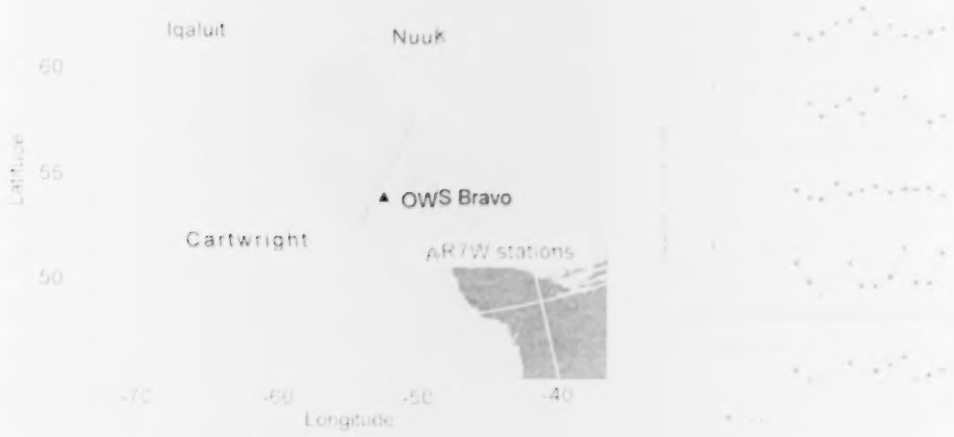
- FOC should develop a shopping list for AZMP in terms of what information it would like to include in an ecosystem status report.
- AZMP questioned the value (if any) of short time series, given that most fixed station sampling began in 1999.
- Spatial representation was considered an issue, e.g. on- versus off-shelf.
- Decision on what indices to select could be determine by the nature of the hypothesis being proposed.
- AZMP was concerned with timing issues, e.g. critical times of the year, e.g. annual average versus spring-time (touches on point above).
- What species should be considered or would the use of bulk properties be sufficient?
- Shifts in seasonal peaks or duration and start up of spring bloom, etc., could be made available.

In order to develop a shopping list, it is imperative to know what is already available from AZMP. Therefore, at the annual meeting of AZMP in 2007, K. Frank compiled a variety of potential data series from the meeting participants. Several data products are being routinely developed that FOC may want to consider. Five examples were provided.

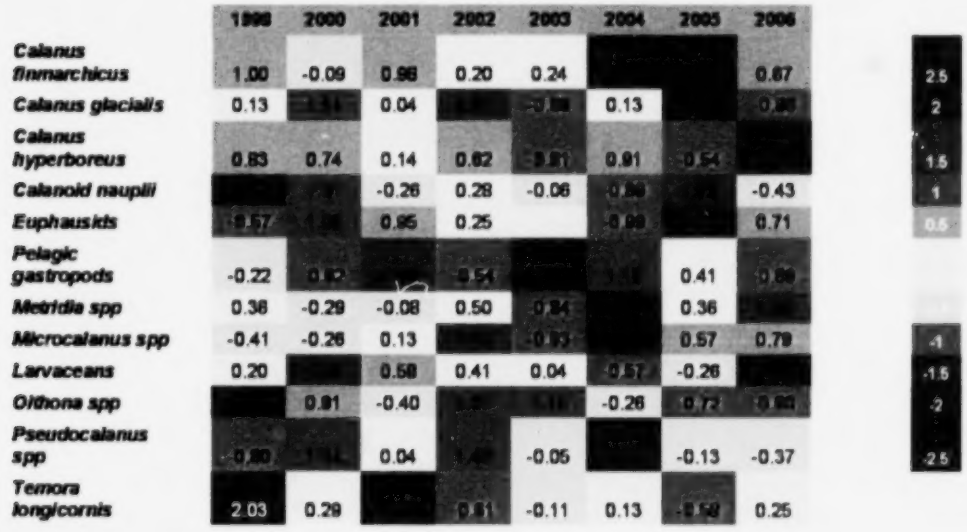
Example 1 *Station 27 - GLM least squares means and standard error estimates for 12 species of dominant zooplankton*

	1999	2000	2001	2002	2003	2004	2005	2006
Calanus finmarchicus	1.00	-0.09	0.98	0.20	0.24	-1.34	-1.86	0.67
Calanus glacialis	0.13	1.11	0.04	1.61	-0.89	0.13	-1.28	-0.86
Calanus hyperboreus	0.83	0.74	0.14	0.62	-0.81	0.91	-0.54	-1.89
Calanoid nauplii	-1.37	1.01	-0.26	0.28	-0.06	-0.89	1.72	-0.43
Euphausids	-0.57	1.08	0.95	0.25		-0.99	-1.43	0.71
Pelagic gastropods	-0.22	-0.62	1.70	-0.54	-1.02	1.18	0.41	-0.89
Metridia spp	0.36	-0.29	-0.08	0.50	-0.84	-1.66	0.36	1.69
Microcalanus spp	-0.41	-0.26	0.13	1.63	-0.93	-1.51	0.57	0.79
Larvaceans	0.20	1.53	0.58	0.41	0.04	-0.57	-0.26	-1.93
Oithona spp	-1.40	0.91	-0.40	1.37	1.10	-0.26	-0.72	-0.60
Pseudocalanus spp	-0.80	1.34	0.04	1.48	-0.05	-1.50	-0.13	-0.37
Temora longicornis	2.03	0.29	-1.40	-0.61	-0.11	0.13	-0.58	0.25

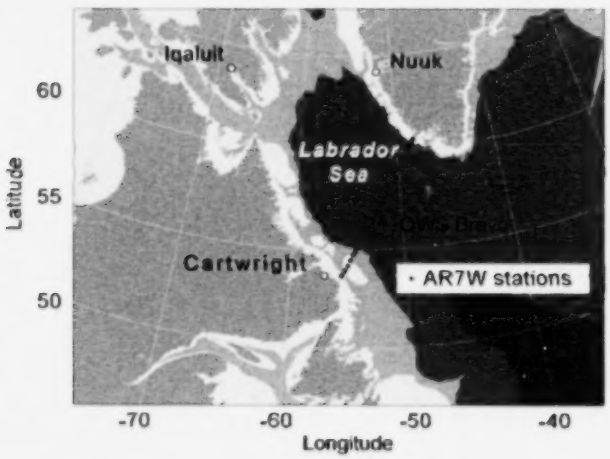
Example 2 *Status of the Labrador Sea 2006 Labrador Sea Monitoring Group. Chemistry-Biology AR7W zooplankton biomass (0–100 m)*

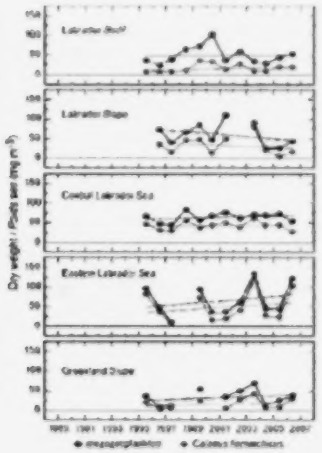


Example 1. *Station 27 - GLM least squares means and standard error estimates for 12 species of dominant zooplankton.*



Example 2. *Status of the Labrador Sea 2006 Labrador Sea Monitoring Group; Chemistry-Biology AR7W zooplankton biomass (0–100 m).*





Example 3. AZMP (fixed stations and sections) in 2006.

AREA	Index	1999	2000	2001	2002	2003	2004	2005	2006
Anticosti Gyre	Zooplancton biomass								
	Total zooplankton abundance	nd							
	Total Copepod abundance	nd							
	Abundance of *C. finmarchicus*								
Gaspé Current	Zooplancton biomass								
	Total zooplankton abundance	nd							
	Total Copepod abundance	nd							
	Abundance of *C. finmarchicus*								
Shediac Valley	Zooplancton biomass								
	Total zooplankton abundance								
	Total Copepod abundance								
	Abundance of *C. finmarchicus*								
TESL	Zooplancton biomass	nd							
	Total zooplankton abundance	nd							
TSI	Zooplancton biomass	nd							
	Total zooplankton abundance	nd							
TASO	Zooplancton biomass	nd							
	Total zooplankton abundance	nd							
TCEN	Zooplancton biomass	nd	nd	nd	nd	nd			
	Total zooplankton abundance	nd	nd	nd	nd	nd			
TDC	Zooplancton biomass	nd							
	Total zooplankton abundance	nd							
TIDM	Zooplancton biomass	nd							
	Total zooplankton abundance	nd							
TBB	Zooplancton biomass	nd							
	Total zooplankton abundance	nd							

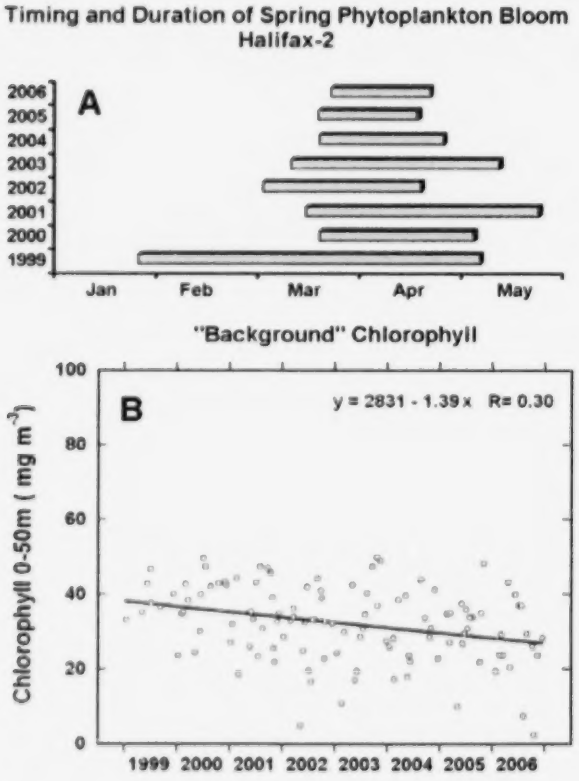
Standard deviation

Positive conditions
- > 2.0
- 1.5 to 2.0
- 1.0 to 1.5
- 0.5 to 1.0

Neutral conditions
- -0.5 to 0.5

Negative conditions
- -0.5 to -1.0
- -1.0 to -1.5
- -1.5 to -2.0
- > 2.0

Example 4. Fixed station data from Station 2 Halifax line.



Example 5. The AZMP environmental indices scorecard.

Part 1. Atmospheric and oceanographic time series expressed as standardized anomalies.

REGION	INDEX	LOCATION	YEAR															
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
NW Atlantic	North Atlantic Oscillation	NW Atlantic		0.33	0.23		0.38			-0.64	-0.34			-0.96	-0.37	-0.39		0.47	-0.39
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Newfoundland/ Labrador	Annual Air Temperature	Labrador (Cartwright)					-0.17	0.20		0.12					0.18				2.56
	Annual Air Temperature	Newfoundland (St. John's)	-0.87				-0.03	-0.33	0.75			2.51		0.79	0.97	0.88			2.19
	Sea Ice Extent	Lab/Nfld (Area)						-0.27		-0.86	-0.66		-0.81			-0.54			
	Sea Surface Temperature	Station 27	0.05	-2.49			0.32		0.32	-0.39	0.80			0.92	-0.08		2.00	2.00	3.22
	Integrated Temperature	Station 27 (0-50)	-0.18	-3.04			0.83	-0.13		0.03	0.18		0.88		-0.11				3.91
	Integrated Temperature	Station 27 (0-176)	-0.13	-2.46			0.16	-0.40	2.47	-0.05	-0.05				0.08		2.95		3.27
	Near-Bottom Temperature	Station 27						-0.38		1.63					0.90	0.63	2.95	2.65	2.70
	Near-Bottom Temperature	Nfld. Grand Bank (Spring)				-0.42		-0.26	0.12		0.96		0.87	-0.14	0.20			0.75	0.98
	Near-Bottom Temperature	3Ps St. Pierre Bank (Spring)							0.40	-0.46	0.45				-0.30		0.40		
	Cold-Intermediate-Layer	Eastern Nfld Shelf			-0.01		-0.03	-0.90	-0.49		-0.35	-0.93	-0.17		-0.96	-0.56			
	Cold-Intermediate-Layer	Grand Bank	-0.03				-0.01	0.26	-0.90	0.26	-0.72			-0.64	-0.90	-0.41	-2.72		-2.70
	Cold-Intermediate-Layer	Hamilton Bank							-0.81		-0.83		0.26	-0.92		-0.43			-0.99
	Surface Salinity	Station 27 (Surface)				-0.94	-0.33		0.22	-0.26	-0.29	-0.37	-0.23					0.44	0.96
	Integrated Salinity	Station 27 (0-50)				-0.17	-0.31		-0.17	-0.20	-0.03	-0.17	-0.44				0.43	0.47	0.91
	Stratification	Station 27		0.07	-0.11		-0.12			0.90			0.83		-0.17	0.03	-0.35	0.27	
	Mixed-Layer-Depth	Station 27			0.11	-0.04			0.80		-0.27	-0.17		0.45		-0.27	2.13	0.09	0.96
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Gulf of St. Lawrence	Annual Air Temperature	Gulf St. Lawrence (Magdalen Islands)	0.13	0.04	-0.41		-0.13	0.18	0.98	-0.20		2.777			0.62	0.83	0.77		2.94
	Sea Surface Temperature	Gulf St. Lawrence (Magdalen Islands) SST	-0.22	-0.18	-0.42		-0.22	0.16	0.20		-0.03		0.27	0.64	0.07	0.20	0.36	0.68	
	Sea Ice Extent (Dec-Apr)	Gulf of St. Lawrence (Area)						0.174	-0.90	-0.39						0.247		-0.8	-2.79
	Integrated Temperature	Cabot Strait (200-300 m)		-2.88			0.03			0.069		0.639	0.14	0.57	0.98	0.39	0.39	0.16	0.19
	Integrated Temperature	Gulf of St. Lawrence (30-100 m)							-0.46			-0.08	0.96		-0.26		-0.20	0.88	
	Integrated Temperature	Gulf of St. Lawrence (100-200 m)		-2.17			-0.08			-0.19		0.89	0.38	-0.10	0.64			-0.14	0.72
	Integrated Temperature	Gulf of St. Lawrence (200-300 m)					0.38	-0.48		0.48	-0.28	0.15	0.10	0.33	0.80	0.05	0.10	-0.20	0.28
	Integrated Salinity	Gulf of St. Lawrence (30-100 m)	0.84	0.10	0.03		-0.17					0.16		-0.24	0.37	0.96	-0.31		-0.17
	Integrated Salinity	Gulf of St. Lawrence (100-200 m)	-0.18				0.13		-2.24			0.19	-0.37		0.13				0.44
	Integrated Salinity	Gulf of St. Lawrence (200-300 m)	-0.45	-2.27		-0.33	0.40			-0.33	-0.08	0.04		-0.21	0.62		-0.21	-0.33	0.74
	Near-Bottom Temperature	Magdalen Sh. Area with T < 0	0.43							0.179			-0.45				-0.29		
	Near-Bottom Temperature	Magdalen Sh. Area with T < 1										-0.57	-0.96	0.06	-0.91	0.42	-0.06	-0.74	
	Cold-Intermediate-Layer	Gulf St. Lawrence Min. Temp.								-0.35		0.23	0.79	0.17	0.23		0.08	0.45	1.99
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Scotian Shelf/ Gulf of Maine	Annual Air Temperature	Scotian Shelf (Sable Island)	0.12	0.12		0.00	0.79	-0.24	-0.07			2.77		0.71	0.35	0.24	-0.33		0.88
	Annual Air Temperature	Gulf of Maine (Boston)				0.00	0.88	-0.13				0.94		0.82					0.67
	Sea Ice Extent	Scotian Shelf (Area)	2.07	0.12				-0.50		-0.42							-0.30		
	Sea Surface Temperature	Halifax (SST)							-0.46	-0.31	0.14	-0.04	0.44						0.46
	Sea Surface Temperature	Bay of Fundy (St. Andrews SST)	1.91	-0.23	-0.19		0.74	0.64	0.89	-0.08	0.84							-0.14	2.60
	Sea Surface Temperature	Gulf of Maine (Boothbay SSTs)	0.43	0.35	-0.16		0.90		0.84	0.35	0.62	2.00	2.38	2.28	3.44	2.38	2.82		3.62
	Near-Bottom Temperature	NE Scotian Shelf (Missine Bank - 160 m)				-0.41				-0.44	-0.03	0.72		-0.33	-0.02	-2.14		0.21	0.78
	Temperature	Emerald Basin (250 m)	0.41	0.22	0.27			0.83	0.94	0.96	-2.66	-0.33	0.32	0.16	0.03	0.06	0.83	0.20	0.44
	Temperature	Lurcher Shoals (90 m)	0.19				-0.13	-0.35		0.05						0.25		-0.37	
	Temperature	Georges Basin (200 m)	-0.43	-0.11	0.17	0.32	0.89		0.94	0.36	-2.62	0.87		0.14	0.45	0.83	0.06	-0.42	0.79
	Temperature	Georges Bank (50 m)	0.27	0.78			0.82	0.43		0.44							-3.17	-2.16	-0.20
	Temperature	Prince 5 (90 m), Bay of Fundy	-0.42	0.23	-2.09			0.82	-0.24							-0.43			2.51
	Salinity	Prince 5 (90 m)	0.84	-0.49				-0.13	-2.03	-0.19		0.91	0.48	-0.16		0.74			0.86

Part 2. Fixed-station data series.

INDEX	LOCATION	REFERENCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
SURFACE TEMPERATURE	HAMILTON BANK	1971-2000	0.38			0.34	0.15	-0.19		0.12		-0.01		0.05	-0.23				
	FLEMISH CAP	1971-2000						0.01	0.17	0.32		0.13	0.85	0.48		0.20	0.53		
	STATION 27	1971-2000	0.05				0.32		0.32	-0.39	0.66			0.92	-0.06				
	ST. PIERRE BANK	1971-2000		-0.01		-0.40		0.74	0.39	-0.41					-0.08	-0.43	0.44		
SURFACE SALINITY	HAMILTON BANK	1971-2000	-0.40	0.07	-0.29			0.74	0.96		-0.21	-0.46	-0.06	0.13		-0.35	-0.09	0.78	0.02
	FLEMISH CAP	1971-2000	0.75	0.47		0.00		0.80	0.69		-0.06	0.82	-0.29						0.96
	STATION 27	1971-2000				-0.04	-0.33		0.22	-0.26	-0.29	-0.37	-0.23				0.59	0.44	0.69
BOTTOM TEMPERATURE	STATION 27	1971-2000						-0.38		0.83					0.99	0.83			
	FLEMISH CAP	1971-2000				-0.41			-0.48	-0.11	0.02		0.36	-0.16	0.11	0.84			
	HAMILTON BANK	1971-2000		-0.45				0.49	0.87		0.85		0.28						0.99
	ST. PIERRE BANK	1971-2000		0.20	-0.47				-0.21	-0.21		0.87	0.79						
VERTICALLY AVERAGED TEMPERATURE	STATION 27 (0-20 M)	1971-2000	0.26				0.82	-0.31	0.87	-0.16					0.18				
	STATION 27 (0-50 M)	1971-2000	-0.18				0.83	-0.13		0.03	0.15		0.95		-0.11				
	STATION 27 (0-100 M)	1971-2000	0.20				0.89	-0.34		-0.33	-0.28		0.87		0.00				
	STATION 27 (0-175 M)	1971-2000	-0.13				0.16	-0.40		-0.05	-0.05				0.68				
	ST. PIERRE BANK (0-75 M)	1971-2000		0.45	-0.26				-0.49		-0.36		0.75		-0.14		0.31	0.86	
VERTICALLY AVERAGED SALINITY	STATION 27 (0-20 M)	1971-2000				0.02	-0.26		0.17	-0.31	-0.24	-0.35	-0.19				0.91	0.48	0.99
	STATION 27 (0-50 M)	1971-2000				-0.17	-0.31		-0.17	-0.20	-0.03	-0.17	-0.44				0.43	0.47	0.91
	STATION 27 (0-100 M)	1971-2000				-0.07				0.16	0.08	-0.32			0.77	0.85	-0.31	0.01	0.77
	STATION 27 (0-175 M)	1971-2000				0.15				0.08	0.16	-0.32			0.49	0.29	-0.49	-0.10	0.77
MIXED-LAYER	STATION 27 (WINTER)	1990-2004							0.94	0.99		-0.13		0.72	0.94	-0.29		0.79	
MIXED-LAYER	STATION 27 (ANNUAL)	1990-2004			0.11	-0.04			0.89		-0.27	-0.17		0.45		-0.27		0.09	0.98
MIXED-LAYER	STATION 27 (SPRING)	1990-2004			-0.13	-0.13	0.38		-0.45				-0.13	0.96	0.91	0.02			-0.07
STRATIFICATION	STATION 27 (ANNUAL)	1971-2000		0.07	-0.11		-0.12			0.86			0.89		-0.17	0.03	-0.35	0.27	
STRATIFICATION	STATION 27 (SPRING)	1971-2000				-0.22				0.05	0.92	0.73	-0.22	0.02			-0.28	0.21	0.87
STRAT ONSET	ONSET (25% OF MAX)	1993-2004				-0.46	0.77		0.50			-0.46	0.93	0.22	0.91	0.91		0.36	0.04
STRAT PHASE	TIME OF MAX AMPLITUDE	1993-2004				0.48	0.23			-0.43			0.86		0.39		0.06	0.84	0.54
10 M TEMPERATURE	STOCK COVE BB	1971-2000	0.44		-0.36		0.93	0.09	0.83		0.96	0.90							
10 M TEMPERATURE	COMFORT COVE NDB	1962-2004					0.11		0.77		-0.11	0.82			0.76	0.82		0.36	-0.02
10 M TEMPERATURE	ARNOLDS COVE PB	1981-2004	0.91				0.56		0.72	-0.26	0.96			0.82	0.88		-0.12	0.44	
5 M TEMPERATURE	BRISTOL'S HOPE	1969-2004					0.84	0.14	0.22	0.06			0.33	0.79	0.18		0.37	0.96	
9 M TEMPERATURE	HAMPDEN WB	1992-2004			-0.24	0.37			-0.20		0.66	0.37			0.75	0.50			
10 M TEMPERATURE	OLD BONAVENTURE	1991-2004						0.17	0.82	-0.01		-0.46	0.09		0.36	0.20	-0.41	0.63	
10 M TEMPERATURE	UPPER GULLIES CB	1990-2004				-0.38	0.39	0.58		0.09			-0.15	0.22	0.50		0.02		

Following the presentation by K. Frank to FOC, there was a discussion on the nature of the FOC request to the AZMP committee for material to be presented at the 2008 joint meeting. A "shopping list" of the FOC needs, as it were, is required. There are several approaches that could be taken:

- outline hypotheses on the functioning of ecosystems (bottom up/top down), and request AZMP for relevant indices;
- define specific fish/environment interactions for which AZMP time series are needed; and
- provide a draft list of AZMP-type indicators that FOC feels would be useful for interpreting fisheries and ecosystem trends.

It was concluded that an iterative approach would be most fruitful, with the aim of defining a limited number of oceanographic indicators (i.e. taking a parsimonious approach).

Example 5 The AZMP environmental indices scorecard

Part 1. Atmospheric and oceanographic time series expressed as standardized anomalies

AZMP PHYSICAL ENVIRONMENTAL INDICES

REGION	INDEX	LOCATION	YEAR															
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
NW Atlantic	North Atlantic Oscillation	NW Atlantic	1.88	0.33	0.23	0.87	0.38	1.27	-1.42	-0.64	-0.34	1.16	1.10	-0.96	-0.37	-0.39	-1.95	0.47	0.39
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Newfoundland Labrador	Annual Air Temperature	Labrador (Cartwright)	-0.94	-1.30	-1.08	-1.01	-0.17	0.29	1.12	0.12	1.23	1.82	1.13	1.22	0.16	1.01	1.79	1.59	2.86
	Annual Air Temperature	Newfoundland (St. John's)	0.07	-1.02	-1.39	-1.14	-0.03	-0.33	0.78	-0.69	1.13	2.01	1.55	0.78	0.07	0.88	1.11	1.26	2.19
	Sea Ice Extent	Lab./Nfld. (Area)	0.67	1.21	1.00	1.66	0.79	-0.27	-1.26	-0.58	-0.96	-1.36	-0.81	-1.36	-1.09	-0.54	-1.93	-1.17	-1.61
	Sea Surface Temperature	Station 27	0.80	-2.00	-1.40	-1.37	0.12	-0.60	0.32	-0.79	0.86	1.81	1.15	0.92	0.08	1.34	2.66	2.21	3.28
	Integrated Temperature	Station 27 (0-50)	0.18	-3.04	-0.57	-0.54	0.63	-0.13	1.62	0.83	0.18	1.26	0.95	1.73	-0.11	1.48	1.96	1.94	3.91
	Integrated Temperature	Station 27 (0-176)	0.13	-2.46	-0.69	-1.04	0.16	0.40	1.49	0.05	-0.05	1.18	1.14	1.25	0.68	1.18	2.99	1.98	3.27
	Near-Bottom Temperature	Station 27	-0.76	-1.42	-0.95	-1.37	-1.18	-0.38	1.24	0.83	1.36	1.43	1.31	1.50	0.60	0.63	2.95	2.88	2.70
	Near-Bottom Temperature	Nfld. Grand Bank (Spring)	-1.17	-1.86	-1.22	-0.42	-0.99	0.26	0.12	-0.81	0.98	1.82	0.57	-0.14	0.20	-0.98	1.25	0.75	0.58
	Near-Bottom Temperature	3Ps St. Pierre Bank (Spring)	-1.41	-0.94	-1.07	-1.01	-0.73	-0.60	0.48	-0.46	0.45	1.29	1.58	-0.53	-0.39	2.84	0.40	1.14	
	Cold-Intermediate-Layer	Eastern Nfld Shelf	-1.66	-1.71	-0.01	0.55	-0.03	-0.99	-0.49	-1.03	-0.35	-0.93	-0.17	-1.24	-0.98	-0.58	-1.72	-1.41	-1.67
	Cold-Intermediate-Layer	Grand Bank	0.03	1.88	0.62	1.26	-0.01	0.26	-0.80	0.26	-0.72	-1.37	-1.25	-0.54	0.80	-0.41	-2.72	-1.06	-3.70
	Cold-Intermediate-Layer	Hamilton Bank	1.26	1.36	0.55	0.71	0.61	-1.22	-0.51	-1.56	-0.63	-1.91	0.26	-0.52	-1.07	-0.43	-1.41	-1.09	-0.65
	Surface Salinity	Station 27 (Surface)	1.48	-1.61	-0.96	-0.04	-0.33	-1.85	0.22	0.26	-0.29	0.57	-0.23	-0.56	1.06	1.01	0.58	0.44	0.65
	Integrated Salinity	Station 27 (0-50)	1.90	-0.80	-1.46	-0.17	-0.11	-1.38	-0.17	-0.20	0.93	-0.17	-0.44	-0.79	1.19	1.16	0.43	0.47	0.61
	Stratification	Station 27	-0.92	0.07	-0.11	-0.79	-0.12	1.55	-1.09	0.56	1.22	1.44	0.68	1.44	0.17	0.03	-0.35	0.27	1.36
	Mixed Layer Depth	Station 27	-0.95	-1.34	0.11	0.04	1.13	-1.37	0.60	-0.60	-0.27	-0.17	-0.50	0.45	1.18	-0.27	-1.13	0.09	0.58
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Gulf of St. Lawrence	Annual Air Temperature	Gulf St. Lawrence (Magdalen Islands)	0.11	0.04	-0.41	-1.24	-0.13	0.16	0.95	-0.26	1.917	2.777	1.47	1.95	0.62	0.83	0.77	1.39	2.84
	Sea Surface Temperature	Gulf St. Lawrence (Magdalen Islands) SST	-0.22	-0.18	-0.42	-0.74	0.22	0.16	0.20	-0.55	-0.01	1.094	0.27	0.54	0.87	0.29	0.18	0.68	1.44
	Sea Ice Extent (Dec-Apr)	Gulf of St. Lawrence (Area)	1.369	0.809	1.03	1.916	1.133	0.174	-0.66	0.39	-1.65	-1.36	-1.95	-1.64	-1.38	0.247	-1.34	-0.8	-2.70
	Integrated Temperature	Cabot Strait (200-300 m)	-1.16	-2.88	-0.67	1.24	0.01	-0.68	-0.53	0.069	-0.81	0.629	0.14	0.57	0.86	0.38	0.39	0.16	0.79
	Integrated Temperature	Gulf of St. Lawrence (30-100 m)	0.91	-1.72	-1.91	-0.69	-1.30	-0.59	-0.48	-0.67	-0.81	-0.08	0.56	-0.73	-0.25	-1.24	0.29	0.68	1.11
	Integrated Temperature	Gulf of St. Lawrence (100-200 m)	0.38	-2.17	-1.69	-1.91	0.08	-1.42	-1.40	-0.19	-0.62	0.59	0.56	-0.10	0.54	-0.60	-0.83	-0.12	0.72
	Integrated Temperature	Gulf of St. Lawrence (200-300 m)	-0.53	-1.97	-1.39	-0.63	0.16	-0.48	-0.96	0.48	-0.24	0.15	-0.10	0.13	0.60	0.08	0.10	-0.20	0.29
	Integrated Salinity	Gulf of St. Lawrence (30-100 m)	0.64	0.16	0.03	-0.99	-0.17	-1.26	-1.71	-1.19	-0.99	0.16	-1.32	-0.24	0.37	0.98	-0.11	-1.32	-0.11
	Integrated Salinity	Gulf of St. Lawrence (100-200 m)	0.18	-1.80	-0.93	-1.05	0.13	-1.49	-2.34	-0.81	-0.81	0.13	-0.37	-0.81	0.13	-0.81	-1.05	-0.74	0.44
	Integrated Salinity	Gulf of St. Lawrence (200-300 m)	-0.41	-2.57	-1.06	0.33	0.40	-0.93	-1.42	0.33	-0.06	0.64	-0.57	-0.21	0.52	-0.57	-0.21	-0.13	0.76
	Near-Bottom Temperature	Magdalen Sh. Area with T < 0	0.41	0.63	1.66	1.49	1.19	1.48	0.59	0.179	0.849	-1.09	-0.45	-1.18	-1.14	0.61	-0.29	-1.21	-1.21
	Near-Bottom Temperature	Magdalen Sh. Area with T < 1	0.60	0.62	1.31	0.52	0.69	1.37	0.68	0.639	1.136	-0.57	-0.99	0.06	-0.81	0.52	0.06	-0.74	-1.13
	Cold-Intermediate-Layer	Gulf St. Lawrence Min. Temp.	-1.05	-1.07	-0.36	-0.81	-1.03	-0.90	-0.62	-0.35	-0.84	0.23	0.79	0.17	0.23	-0.94	0.08	0.45	1.00
			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Scotian Shelf Gulf of Maine	Annual Air Temperature	Scotian Shelf (Sable Island)	0.12	0.17	-0.78	0.00	0.75	0.24	-0.07	-0.92	1.28	2.77	1.95	0.71	0.35	0.24	-0.33	1.03	0.68
	Annual Air Temperature	Gulf of Maine (Boston)	1.62	1.80	-1.36	0.00	0.59	-0.13	-0.81	-0.77	1.32	0.94	-1.01	0.81	1.19	-1.47	-0.90	-0.63	0.57
	Sea Ice Extent	Scotian Shelf (Area)	2.07	0.12	1.02	0.82	0.84	-0.58	-1.16	-0.42	-1.45	-1.33	-1.26	-1.13	-1.32	1.08	-0.10	-1.01	-1.46
	Sea Surface Temperature	Halifax (SST)	-0.52	-0.63	-1.32	-1.19	-0.91	-0.91	-0.46	-0.31	0.14	-0.04	0.44	-0.95	-0.55	-1.00	-1.88	-1.48	0.46
	Sea Surface Temperature	Bay of Fundy (St. Andrews SST)	-0.54	0.23	-0.19	-1.17	0.74	0.64	0.60	0.08	0.54	1.87	1.57		1.26	-0.60	-1.47	-0.13	1.86
	Sea Surface Temperature	Gulf of Maine (Boothbay SSTs)	0.43	0.35	-0.16	-0.78	0.80	1.09	0.64	0.35	0.52	2.08	2.08	1.31	3.04	2.04			
	Near-Bottom Temperature	NE Scotian Shelf (Misaine Bank - 100 m)	-1.85	-1.84	-0.93	-0.41	-0.55	-0.99	-0.58	0.44	0.03	0.79	1.35	0.13	-0.02	-2.10	-1.07	0.21	0.78
	Temperature	Emerald Basin (250 m)	0.11	0.22	0.27	1.01	1.00	0.63	0.84	0.54	-2.08	-0.33	0.12	0.16	0.83	0.65	0.53	0.20	0.44
	Temperature	Lurcher Shoals (50 m)	0.19	1.61	-0.81	-0.60	0.11	-0.35	-1.01	0.05	-1.44	1.12	1.74	-0.88	1.25	0.25	-1.20	-0.37	1.59
	Temperature	Georges Basin (200 m)	-0.43	-0.11	0.17	0.32	0.89	1.19	0.96	0.18	-2.82	0.97	1.01	0.14	0.45	0.85	0.06	-0.42	0.70
	Temperature	Georges Bank (50 m)	0.27	0.79	-0.96	-0.95	0.52	0.41	-0.84	0.44	-0.85	1.15	1.15	1.52	1.51	-1.07	-3.17	-2.11	0.20
	Temperature	Prince 5 (30 m), Bay of Fundy	-0.42	0.21	-2.89	-1.96	1.34	0.55	0.24	-1.22	-0.78	1.86	1.66	-0.52	1.52	-0.43	-1.69	-0.66	2.55
	Salinity	Prince 5 (30 m)	0.95	-0.49	-1.97	-1.30	1.06	0.11	-2.80	-0.19	-1.00	0.80	0.49	-0.16	1.34	0.77	-0.52	-0.73	0.60

Part 2: Fixed-station data series

STANDARIZED PHYSICAL ENVIRONMENTAL ANOMALIES (FIXED SITES)

INDEX	LOCATION	REFERENCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
SURFACE TEMPERATURE	HAMILTON BANK	1971-2000	0.38	-0.87	-0.56	0.34	0.15	-0.19	-0.52	0.12		-0.01	1.75	0.05	-0.23		2.03		1.43
	FLEMISH CAP	1971-2000	-0.51	-1.30	-1.84	-1.91	-0.73	0.01	0.17	0.32		0.13	0.85	0.48	-0.66	0.20	0.53	1.97	2.29
	STATION 27	1971-2000	0.05		-1.40	-1.37	0.32	-0.60	0.32	-0.39	0.86	1.81	1.15	0.92	-0.08	1.34	2.00	2.00	
	ST. PIERRE BANK	1971-2000	-1.87	-0.01	-1.24	-0.40	-0.72	0.74	0.39	-0.41	1.13	1.21	1.51	-0.82	0.08	-0.43	0.44	2.18	
SURFACE SALINITY	HAMILTON BANK	1971-2000	-0.40	0.07	-0.29	-1.06	-1.01	0.74	0.56	1.04	-0.21	-0.46	-0.06	0.13	-0.51	-0.35	-0.09	0.73	0.02
	FLEMISH CAP	1971-2000	0.75	0.47		0.00	-1.38	0.80	0.60	1.14	-0.06	0.82	-0.29	1.26	1.49	2.27	1.46	1.20	0.56
	STATION 27	1971-2000	1.48		-0.96	-0.04	-0.33	-1.92	0.22	-0.26	-0.29	-0.37	-0.23	-0.56	1.06	1.01	0.58	0.44	0.65
BOTTOM TEMPERATURE	STATION 27	1971-2000	-0.76	-1.42	-0.95	-1.37	-1.16	-0.38	1.24	0.83	1.36	1.43	1.31	1.50	0.60	0.63			
	FLEMISH CAP	1971-2000		-1.02	-0.66	-0.41		-0.51	-0.48	-0.11	0.82	1.78	0.36	-0.16	0.11	0.84	1.08	2.12	1.40
	HAMILTON BANK	1971-2000	-1.19	-0.45	-0.96	-1.29	-0.64	0.49	0.67	1.71	0.65	1.56	0.28	1.79	1.72	1.19	2.25	1.86	0.66
	ST. PIERRE BANK	1971-2000	-1.26	0.20	-0.47	-0.69	-1.78	-1.07	-0.21	-0.21	-0.61	0.67	0.70	-0.53	-0.62	-1.11	1.29		
VERTICALLY AVERAGED TEMPERATURE	STATION 27 (0-20 M)	1971-2000	0.26		-1.10	-1.22	0.62	-0.31	0.67	-0.10	1.00	2.10	1.00	1.25	0.18	1.53	2.11	1.97	
	STATION 27 (0-50 M)	1971-2000	-0.18		-0.57	-0.54	0.63	-0.13	1.62	0.03	0.18	1.26	0.95	1.73	-0.11	1.48	1.96	1.94	
	STATION 27 (0-100 M)	1971-2000	0.20		-0.59	-0.89	0.59	-0.34	2.24	-0.33	-0.28	1.23	0.87	1.12	0.56	1.30		1.39	
	STATION 27 (0-175 M)	1971-2000	-0.13		-0.69	-1.04	0.16	-0.40	2.47	-0.05	-0.05	1.18	1.14	1.25	0.68	1.18		1.98	
	ST. PIERRE BANK (0-75 M)	1971-2000		0.45	-0.26	-0.87	-1.47	-1.27	-0.49	-1.61	-0.36	1.94	0.75	-0.65	-0.14	-0.59	0.31	0.84	
VERTICALLY AVERAGED SALINITY	STATION 27 (0-20 M)	1971-2000	1.57	1.81	-0.95	0.02	-0.26	-1.77	0.17	-0.31	-0.24	-0.35	-0.19	-0.62	1.10	1.08	0.61	0.48	0.66
	STATION 27 (0-50 M)	1971-2000	1.90	-1.86	-1.46	-0.17	-0.31	-1.35	-0.17	-0.20	-0.03	-0.17	-0.44	-0.79	1.10	1.16	0.43	0.47	0.61
	STATION 27 (0-100 M)	1971-2000	1.91	-1.37	-1.67	-0.07	-0.63	-1.00	-0.74	0.16	0.08	-0.32	-0.71	-0.78	0.77	0.85	-0.31	0.01	0.77
	STATION 27 (0-175 M)	1971-2000	1.61	-1.41	-1.84	0.15	-0.63	-0.65	-1.07	0.08	0.16	-0.32	-0.50	-0.90	0.49	0.29	-0.49	-0.10	0.77
MIXED LAYER	STATION 27 (WINTER)	1990-2004	-0.76	-1.11	-0.83	-0.92	1.39	-0.86	0.88	0.69	-0.78	-0.13	-0.90	0.72	0.94	-0.29	1.95	0.79	2.14
MIXED LAYER	STATION 27 (ANNUAL)	1990-2004	-0.95	-1.34	0.11	-0.04	1.13	-1.40	0.60	-0.60	-0.27	0.17	-0.50	0.45	1.18	-0.27	2.18	0.09	0.58
MIXED LAYER	STATION 27 (SPRING)	1990-2004	-0.72	-0.79	-0.13	0.13	0.38	-1.21	-0.45	-1.29	1.55	-1.11	-0.13	0.98	0.91	0.02	2.03	-0.64	-0.07
STRATIFICATION	STATION 27 (ANNUAL)	1971-2000	-0.92	0.07	-0.11	-0.79	-0.12	1.55	-1.09	0.56	1.22	1.44	0.68	1.44	-0.17	0.03	-0.35	0.27	1.36
STRATIFICATION	STATION 27 (SPRING)	1971-2000	-1.31	-0.63	-0.93	-0.22	-0.51	1.60	-0.75	0.05	0.92	0.73	-0.22	0.02	-0.91	-0.89	-0.28	0.21	0.57
STRAT ONSET	ONSET (25% OF MAX)	1993-2004				-0.46	0.77		0.50	-1.01	-1.01	-0.46	0.63	0.22	0.91	0.91	1.09	0.36	0.04
STRAT PHASE	TIME OF MAX AMPLITUDE	1993-2004				0.48	0.23	-1.35	1.72	-0.43	-1.10	-1.33	0.56	-0.60	0.19	1.39	0.06	0.64	0.64
10 M TEMPERATURE	STOCK COVE BB	1971-2000	0.44	-1.76	-0.36	-1.70	0.98	0.09	0.53	-0.70	0.96	0.90	1.18	1.33	1.08	1.32	1.05	1.44	1.81
10 M TEMPERATURE	COMFORT COVE NDB	1982-2004	1.14	-1.98	-0.73	-1.71	0.11	-1.07	0.77	-0.62	-0.11	0.92	1.08		0.70	0.82		0.38	-0.02
10 M TEMPERATURE	ARNOLDS COVE PB	1981-2004	0.81	-1.36	-1.23	-1.42	0.56	-0.68	0.72	-0.26	0.56	2.33	1.03	0.52	0.59	1.10	-0.12	0.44	1.18
5 M TEMPERATURE	BRISTOL'S HOPE	1989-2004	-0.57			-0.52	0.64	0.14	0.22	0.06	-0.54	1.15	0.83	0.78	0.18	1.03	0.37	0.98	1.07
9 M TEMPERATURE	HAMPDEN WB	1992-2004			-0.24	0.37	-1.32		-0.20	-0.72	0.60	0.37	1.61	-0.73	0.75	0.50	1.02	1.11	1.63
10 M TEMPERATURE	OLD BONAVENTURE	1991-2004		-1.76	-1.11	-0.98	2.85	0.17	0.62	-0.01		-0.46	0.09	1.25	0.36	0.20	-0.41	0.63	1.20
10 M TEMPERATURE	UPPER GULLIES CB	1990-2004	-1.44	-1.57	1.13	-0.38	0.39	0.50	-1.03	0.00	-1.23	1.78	-0.15	0.22	0.50	1.26	0.02	1.85	1.93

Following the presentation by K. Frank to FOC, there was a discussion on the nature of the FOC request to the AZMP committee for material to be presented at the 2008 joint meeting. A "shopping list" of the FOC needs, as it were, is required. There are several approaches that could be taken:

- outline hypotheses on the functioning of ecosystems (bottom up/top down), and request AZMP for relevant indices;
- define specific fish/environment interactions for which AZMP time series are needed; and
- provide a draft list of AZMP-type indicators that FOC feels would be useful for interpreting fisheries and ecosystem trends.

It was concluded that an iterative approach would be most fruitful, with the aim of defining a limited number of oceanographic indicators (i.e. taking a parsimonious approach).

4.0 REGIONAL TRENDS IN CONDITION OF INVERTEBRATES, FISH, AND MARINE MAMMALS

4.1 Trends in the Condition of Marine Fishes in the Southern Gulf of St. Lawrence, 1971 to 2006: Summary for the FOC 2007 Annual Meeting

H. Benoît presented a paper on this topic.

Preliminary analyses were undertaken aimed at describing and understanding the causes of changes in the condition of marine fishes in the southern Gulf of St. Lawrence (sGSL) over the period of 1971-2006. The focus was on trends in the average condition of individuals of a given species. For the purposes of this work, condition was defined as the intact somatic weight (i.e. including the weight of all viscera and stomach contents) of individual fishes as a function of length.

Allocation of energy to stored reserves is but one of many pathways in a dynamic energy budget, where intake may also be directed to activity, somatic growth, reproductive tissues, and routine maintenance (Kooijman 2000). Interpreting the causes of changes in condition (interpreted here as reflecting mainly stored reserves) in light of these allocation "decisions" is therefore not straightforward. While this was borne in mind when formulating hypotheses about potential causes of changes in sGSL fish condition, the analyses presented here did not consider the specific allocations of energy and the results should therefore be interpreted as exploratory.

Changes in condition were hypothesized to potentially result from 3 general effects: direct energy limitation resulting from environmental change or changes in the magnitude of competitive interactions, a direct effect of size (girth) selective fishing mortality in net gear, and indirect effects of environmental change and fishing via changes in growth rates (e.g. Swain et al. 2007) and reproductive schedules (e.g. Olsen et al. 2004) and investment.

The influence of direct energy limitation was examined from two perspectives. The first was from that of individual species, where time series of condition were related to time series of abundance-weighted mean bottom-water temperatures and the biomass of conspecifics (assumed to be the strongest competitors for the species). Sufficient time series of prey abundance were not available for inclusion in the analysis. Because of very strong seasonal patterns in the condition of fishes resulting from a non-feeding overwintering period for most species, interannual patterns in condition resulting from the direct effects of energy limitation were assumed to reflect environmental conditions in the same years. While it was impossible to anticipate the direction of the temperature effect *a priori* given that it will depend on the environmental conditions in relation to thermal optima of metabolism for each species, density dependence was expected to have a negative effect on condition. In fact, it is reasonable to assume that species with the highest densities in the sGSL should display the strongest effects of density-dependence. The second approach to understanding the direct effects of energy limitation was an interspecific comparative one, essentially seeking to test if species displaying similar trends in condition also shared similar habitats (suggesting a common environmental effect) or similar prey (reflecting changes in prey quantity and quality).

Although there is evidence in sGSL cod of an evolutionary response to long-term size-selective fishing on length-at-age (Sinclair et al. 2002a, 2002b; Swain et al. 2007), the data required to directly test for an effect on condition-at-age is not available for that species or others. A very indirect approach was therefore used, again by comparing species. It was hypothesized *a priori* that girth-selective effects should be strongest, and the resulting patterns in condition most

similar, in the most exploited species and should differ among taxonomic groups depending on the manner in which fishing gear selects individuals. Where fishing gear is retaining fish based on their size, this should logically occur based on overall girth for roundfish, whereas in flatfishes the widest axis (dorsal-pectoral) and in skates the overall diameter of the ball formed when they roll in their wings when encountering mobile gear should determine retention. It seems reasonable to hypothesize that while girth of roundfish would be strongly related to condition, the widest diameter of flatfish and skates would be much less so. Under a direct effect of size selective fishing, similarity in condition time series should follow these morphological/taxonomic distinctions.

While the aforementioned indirect effects of environmental changes and size-selective fishing on condition, acting via the dynamic allocation of energy following changes in length-at-age and reproductive investment, are very plausible and scientifically interesting, the data required to address properly the question were generally unavailable and the analyses involved were beyond the scope of the present work. This nonetheless constitutes an important avenue for future research if changes in condition are to be interpreted in the context of overall ecosystem change and "health".

Methods

Representative length frequencies and stratified weight measurements have been obtained for all species during all sets in the sGSL surveys since 1971. Fish were weighed using spring scales (accuracy ± ~10g) from 1971-1989 and with electronic marine scales (±1 g for small-bodied species measured on fine scales and ±5 g for others) since then. Because of these measurement errors, 2 suites of analyses were undertaken. In the 1st, only individual weights >20 g and species with a median weight of >20 g were retained to produce time series of condition for the period 1971-2006. The 2nd included all weights and all species occurring in at least 90% of years, for the period 1990-2006.

Predicted weight as a function of length was used as the measure of condition. This circumvents the well-known problems associated with allometric growth for the oft-used measure of condition, Fulton's K ($K=W \cdot L^{-3}$) (Bolger and Connolly 1989). While there are no problems analyzing temporal trends in K for a given length, the measure is inappropriate when trends in average condition in the population are of interest as was the case here. The model used to get a predicted weight was of the form:

$$(1)\ \ln W_{ijkg} = \beta_0 + \beta_1 G_{ijk} + \beta_2 G_{ijk} \cdot \ln L_{ijkg} + \beta_3 \ln L_{ijkg} + \varepsilon_{ijkg}$$

where $\ln W_{ijkg}$ is the $\log_e$-transformed weight of fish k of gender g in set j of year i, β_0 is the intercept, β_1 is a vector of parameters for the class variable gender (G), β_2 is a vector of parameters for the interaction between gender and $\log_e$-transformed length ($\ln L$), β_3 is the slope parameter for the effect of $\ln L$ and ε is the model residual for the fish. This model takes into account dimorphic growth in flatfish, skates, white hake, and redfish. The model was fit using a least-squares approach in a linear modeling framework. Each observation was weighted to account for the stratified sampling of weights, the relative abundance of the species in the set, and for the proportion of the survey area represented by the set, so as to obtain a true population-level estimate of condition. The residuals from model (1) were then included in a 2nd model of the form:

$$\varepsilon_{ijkg} = \beta_4 + s_1(T_{ji}) + s_2(Y_i) + \varepsilon_{ijkg}$$

where $s_1(T_{ji})$ is a cubic spline function of the time of day in which set j took place and $s_2(Y_i)$ is a cubic spline function of year. The effective degrees of freedom for the 2 spline terms were set to 10 to ensure that the smoothing did not unduly mask underlying temporal variability in the mean trends. It was necessary to account for a potential bias of the effect of time of day on condition because the sGSL survey operated only during the daytime (07:00-19:00 h) from 1971-1984 and 24 h per day thereafter. Diel patterns in weight-at-length are presumably related to fish feeding periodicity and should be independent of diel difference in catchability for which survey catch rates are adjusted anyways (see Benoît and Swain 2003). The cubic spline $s_2(Y_i)$ was used as the interannual trend in condition in all subsequent analyses.

The comparative analyses relate the interspecies differences in interannual trends in condition (species x year matrix) to the traits of those species (species x trait matrix), with statistical testing of both marginal (single trait) and partial significance using permutations. Specifically, it is the symmetrical species dissimilarity matrix calculated from the species x year matrix that serves as the dependent variable in a non-parametric linear model using distance-based redundancy analysis (db-RDA; McArdle and Anderson 2001). The analyses are founded on the idea that if species traits (e.g. prey preference) are mechanistically linked to external factors potentially affecting condition (e.g. the abundance of particular prey types), species with similar traits should display similar trends in condition as a result of changes the inferred causal factor. The traits included in the analysis were: mean body length; mean depth occupied; the relative level of exploitation; whether the species was demersal or pelagic (vertical habitat), roundfish or flatfish/skate; and the food habits of species. The latter trait was scored using multiple modalities (i.e. categories within the trait to represent the proportion of different prey categories) and transformed using fuzzy coding (e.g. Chevenet et al. 1994). Additional details on the multivariate trait-based comparative approach, as well as on the data inputs and trait scoring can be found in Benoît and Swain 2007 (or contact the lead author for details).

Results

There were 23 species for which sufficient data were available to examine interannual trends in condition since 1971 (Fig. 1). Although condition has varied considerably within and among species, the community as a whole has not shown the directional trends in condition observed for the community on the eastern Scotian Shelf (DFO 2003). The trait characterizing species as either pelagic or demersal was the only 1 that was significantly related to interspecific differences in condition (P=0.005). Pelagic fishes tended to have a peak in condition during the mid to late 1970s, and lower condition thereafter, whereas patterns have been more varied for the demersal fishes. Though the effect was not statistically significant, there was evidence that species occurring at similar depths also had similar trends in condition, suggesting common environmental influences. There was no significant difference between roundfish and flatfish/skates in the condition trends, suggesting that any condition-selective fishing, if present, did not fall along those morphological lines.

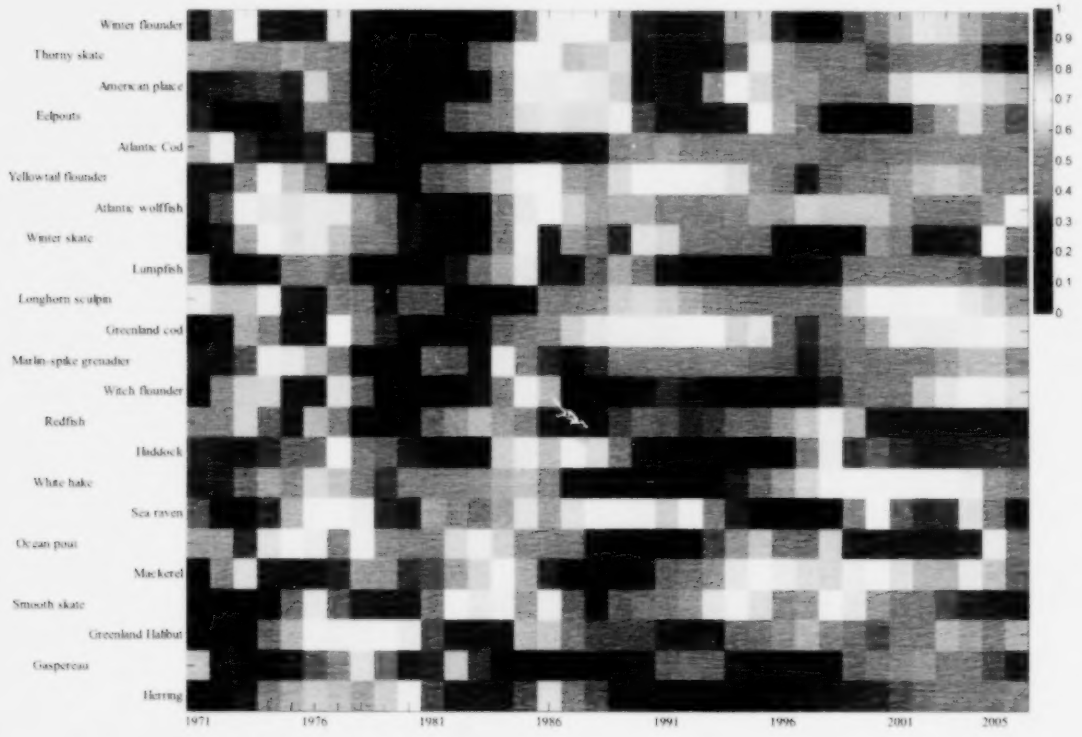


Figure 1. Trends in mean condition of 23 species of sGSL marine fish, 1971-2006. Individual species condition series were transformed to range over the interval [0,1] by subtracting the smallest value from each observation and dividing by the range, and were colour coded accordingly (red=relatively high condition for that species). Species (rows) were sorted using the 1st eigenvector of a correspondence analysis of the species x year matrix to highlight the major trends in condition over time.

A significant (at $\alpha = 0.05$) effect of conspecific density on condition was found for 6 of these species (e.g. Fig. 2). This is greater than the approximate 3 significant cases that would be predicted by chance alone at $\alpha = 0.05$ (based on binomial probability). As predicted, the strength of density dependence was inversely related to the absolute abundance of each species (Fig. 3, $r = -0.60$). In the individual species analyses, a significant effect of abundance-weighted mean temperature on annual condition values was also found for 5 species.

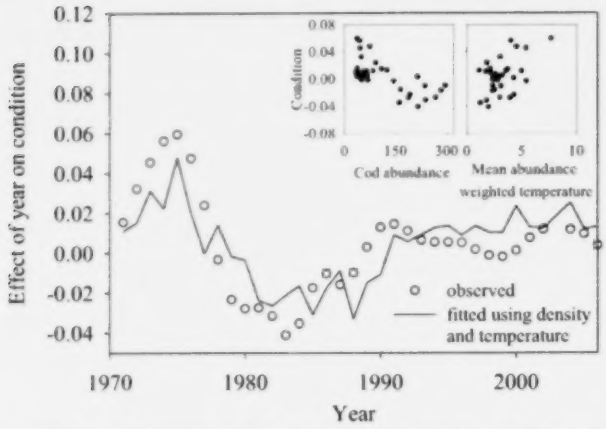


Figure 2. Observed trends in the condition of sGSL Atlantic cod, 1971-2006, along with values predicted by a model including cod abundance and abundance-weighted mean temperatures. Inset figures show the relationships between condition and both cod abundance and mean temperatures for cod.

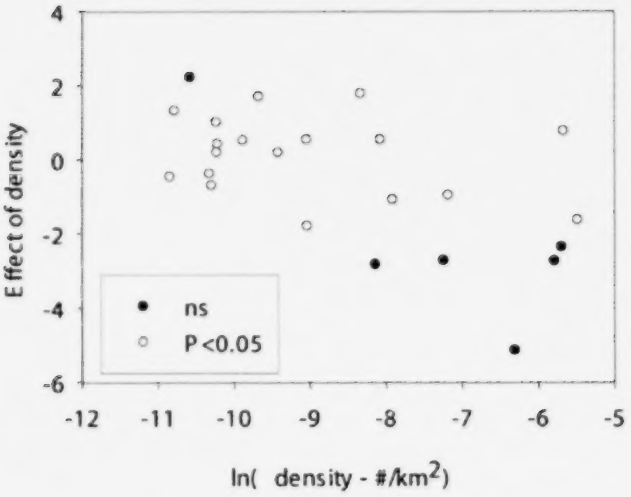


Figure 3. Interspecific relationship between the mean density of each fish species and the effect of fish abundance (T-value=parameter value/SE) from the individual analyses relating each species' interannual values of condition to their abundance and mean abundance-weighted bottom temperatures. Cases where fish abundance was significantly related to abundance are indicated in black.

There were 46 species for which sufficient data were available to examine interannual trends in condition since 1990 (Fig. 4). Similarity in condition time trends were significantly related to similarity in 3 species traits: depth habitat occupied (P=0.006, R^2=0.18), pelagic/demersal (P=0.007, R^2=0.08), and mean body size (P<0.001, R^2=0.15). The influence of latter 2 traits remained significant in partial db-RDA analyses (P=0.041 and P=0.034, respectively). Shallow-water species (<50 m), which includes many of the pelagic fishes in the community, were in relatively good condition both early and late in the time series, though at relatively low condition

during the mid to late 1990s. Mid-water species (50-125 m) were generally in good condition early in the series and at relatively lower condition after the late 1990s. Time trends varied considerably among deeper water species, with few showing long-term trends in condition. The habitat-specific patterns in condition are consistent with long-term changes in temperature that have occurred in the bottom-waters of the sGSL (Drinkwater and Gilbert 2004). Temperatures in the cold intermediate layer (approximately 30-150 m) cooled progressively throughout the 1980s, resulting in several consecutive years during the early to mid 1990s of the coldest temperatures recorded in over 50 years of monitoring (Drinkwater and Gilbert 2004). Since the mid 1990s, there has been a progressive warming of these waters to more average temperatures. Meanwhile, the warmer and deeper waters of the Laurentian Channel did not experience any major trends in temperature.

In general, the condition of smaller-bodied species has decreased since the early 1990s. This is consistent with large increases in the biomass of almost all small-bodied fish species in the sGSL (Benoît and Swain 2007), suggesting possible density-dependent competitive effects. However, possible effects of changes over time in the accuracy with which the weight of the smallest fish was measured cannot be ruled out at this point and needs to be investigated.

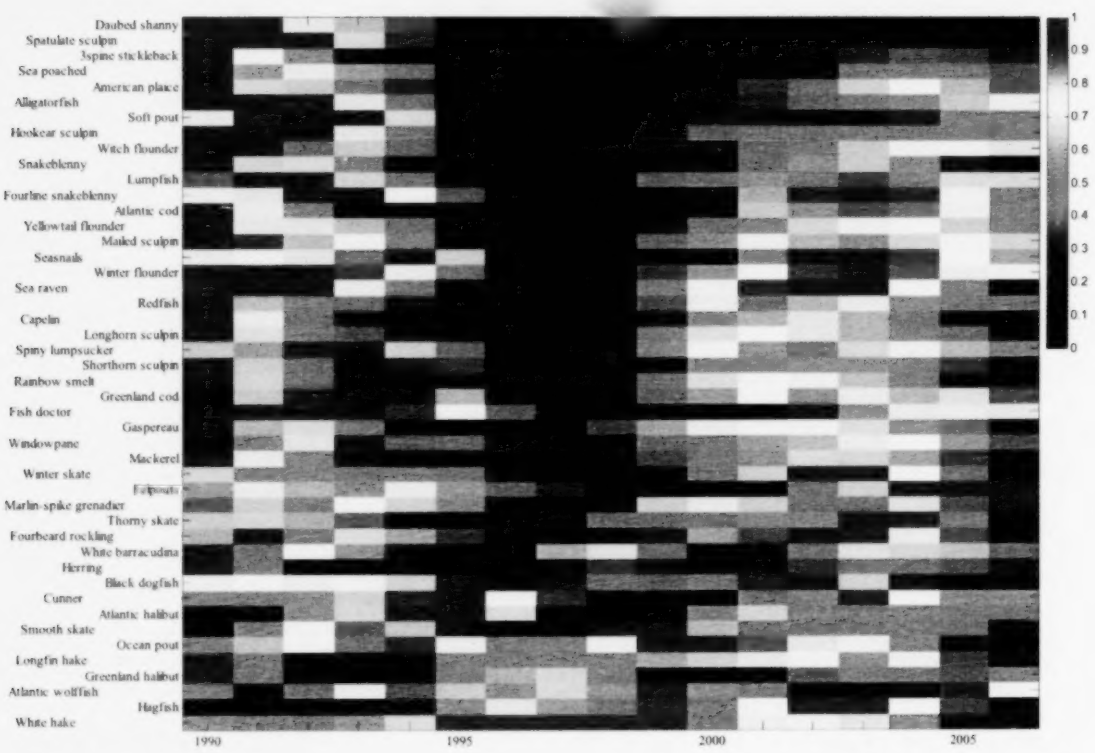


Figure 4. Trends in mean condition of 46 species of sGSL marine fish, 1990-2006. Data were treated as in Fig. 1 prior to plotting.

4.2 Trends in Condition of Some Fish and Invertebrate Species/Stocks in the Gulf of St. Lawrence

P. Ouellet presented a paper on this topic (along with C. Savenkoff, Y. Lambert, F. Gregoire, B. Bernier, L. Savard, M. Harvey, and A. Frechet as co-authors).

Data on growth, length-weight relationships, and the allometric condition index (Fulton's *K*) were presented for few groundfish and pelagic fish species, for northern shrimp (*Pandalus borealis*) and 2 Euphausiid species (*Meganyctiphanes norvegica* and *Thysanoessa raschi*). Information on groundfish species were extracted from the RV surveys database, whereas data for pelagic fish and northern shrimp are from the fisheries sampling program. The zooplankton data were available from the macrozooplankton monitoring program carried on in the Lower St. Lawrence Estuary (LSLE) since 1994 by Institut Maurice-Lamontagne (IML).

The condition indices were estimated using a standard allometric coefficient of 3 (i.e. $K=100(W\ L^{-3})$. That is, at this stage no effort was made to calculate or adjust the allometric coefficient for each specific length–weight relationships. In addition, cod (*Gadus morhua*) is the only species for which, following the work of Lambert and Dutil (1997a, 1997b), condition factor has been shown to be an accurate indicator of the fish energy reserves.

From low values recorded in 1992, a recent increasing trend is observed in mean weight and mean length-at-age of cod, especially for 6- and 8-year-old fish (Fig. 5). There are significant seasonal variations in the condition factor of cod in the northern Gulf. Condition also varies in relation to the morphology and physiology of the fish so that relationships between condition and environmental variables are not constant in space and time. Nonetheless, time series of the condition factor of a 50 cm cod in January (seasonal maximum) and May (seasonal minimum) from 1984 to 2006 show a significant decrease that began in 1989 to continue until reaching the lowest values between 1992 and 1994. Since 1995, a significant increase is observed and condition factors between 2000 and 2006 are at similar levels than those observed for the 1984 to 1989 period.

For Greenland halibut (*Reinhardtius hippoglossoides*), the Fulton index is estimated since 1995 only; and no significant trend in the condition factor (fish >40 cm total length only) is apparent for the 1995 to 2006 period. However, length-weight relationships for Greenland halibut and redfishes (*Sebastes* spp.), averaged by 5-year periods from 1987 to 2005, indicate that weight-at-length values were lower between 1990 and 1994.

In NAFO Div. 4R herring (*Clupea harengus*), for both the spring and the fall spawners, length and weight-at-age were greater in the years 1980 to 1989 relative to the other periods (Fig. 6). Important seasonal variations in the condition factor are revealed in spring spawners with minimum values observed in the spring (spawning season) and maximum in the fall (Fig. 7). The pattern suggests a strategy of maturation and eggs production based on energy reserves accumulated during the previous summer and fall feeding seasons. In contrast, no such seasonal variations are observed for the fall spawners suggesting that the spawning effort is supported with energy assimilated during the reproductive season. In addition, the spring condition factor for spring spawners show indication of a negative trend from the mid 1980s to the mid 1990s (Fig. 7). Low values of the condition factor are observed during the mid 1990s for the fall spawners (Fig. 7).

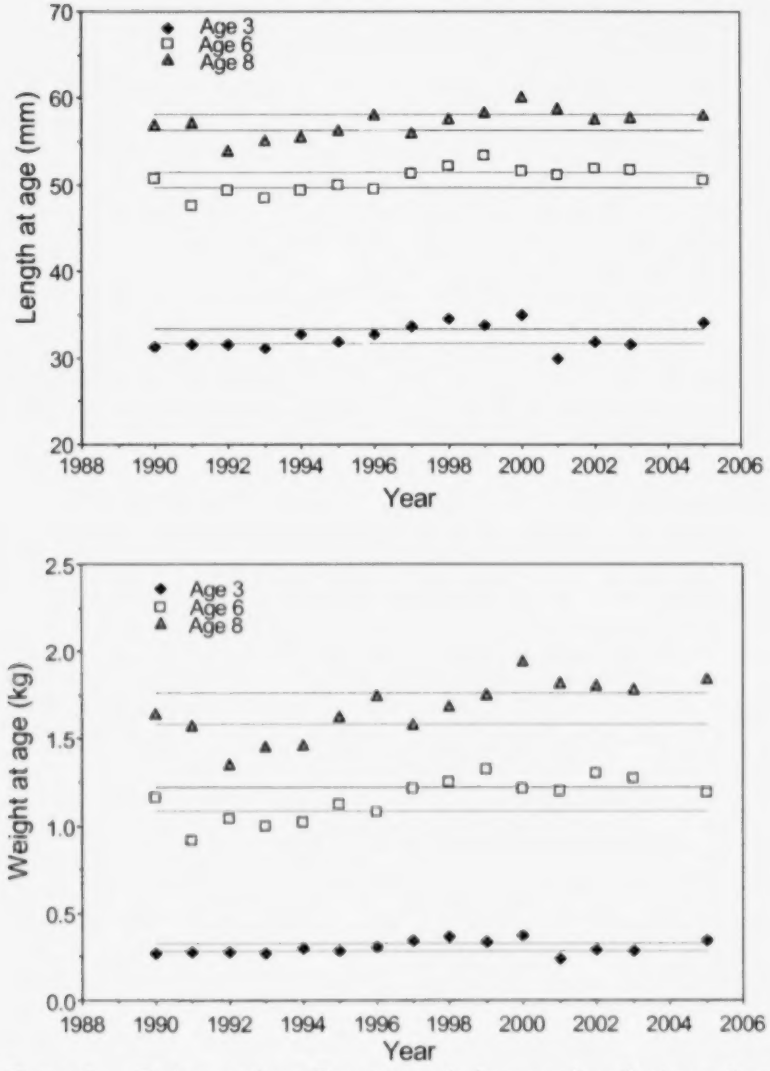


Figure 5. Gadus morhua: Recent trends in mean length-at-age (top panel) and mean weight-at-age (lower panel) for cod of ages 3, 6, and 8. For each relationship, the horizontal lines represent the upper and lower confidence intervals (95%) of the mean.

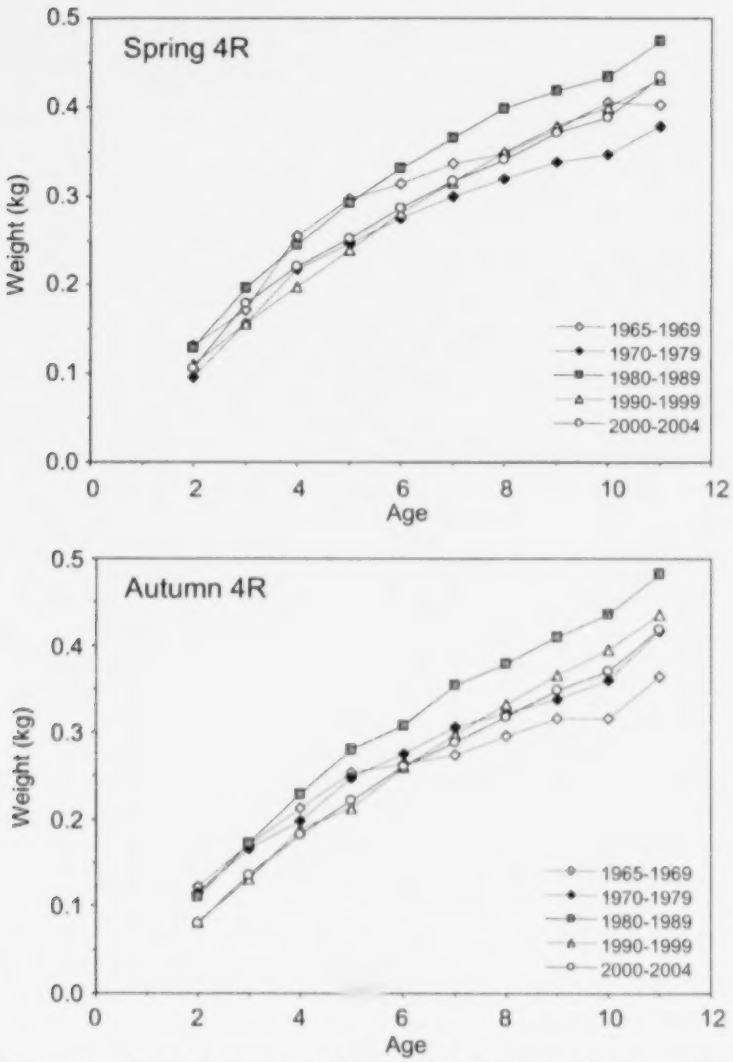


Figure 6. Clupea harengus: Mean weight-at-age for herring spring and fall spawners by 5- and 10-year periods, from the mid 1960s to 2004.

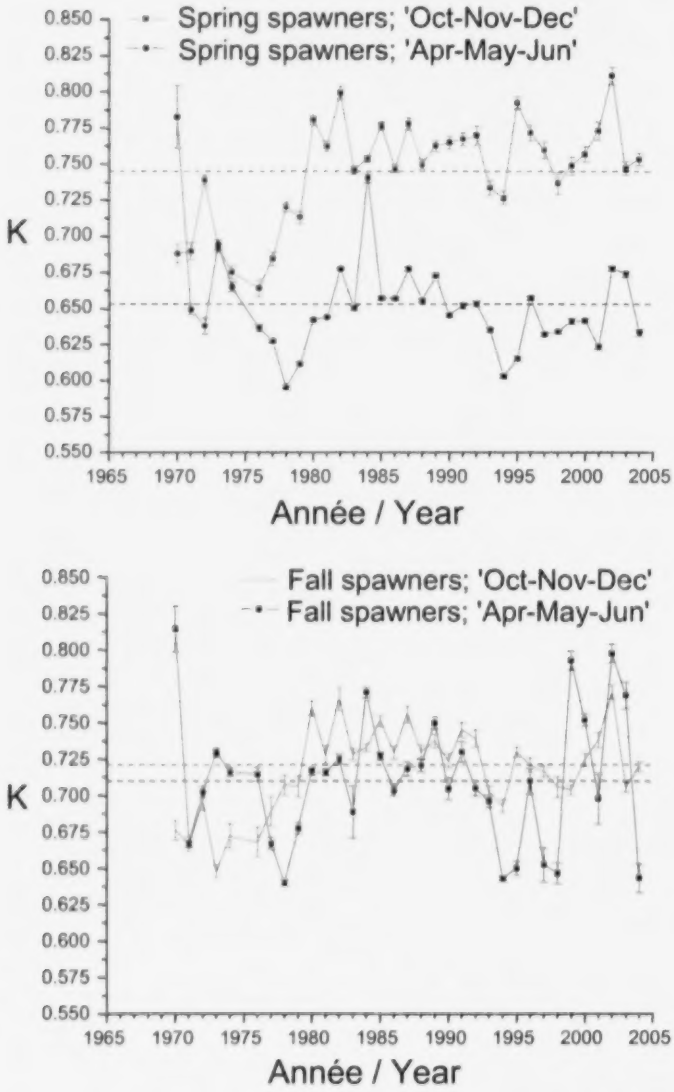
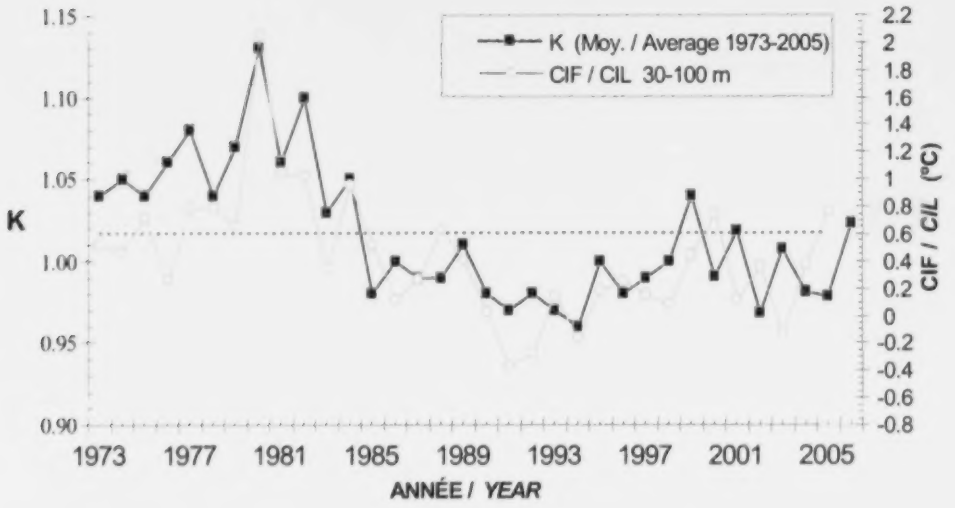


Figure 7. Clupea harengus: Time series of condition factor for herring spring spawners measured in the spring and the fall (top panel) and for fall spawners measured in the spring and the fall (lower panel). For each series, the horizontal line represents the mean condition for the entire period.

Time series of condition factor for Atlantic mackerel (*Scomber scombrus*) in the sGSL are available from 1973 to the present. Age and strength of the year-class seems to influence the condition factor (i.e. growth was slower for abundant year-classes). The time series of mean condition factor (all ages from 3 to 9) show a decline from a maximum in 1981 to the lowest values in the early 1990s; condition factors then rise again until 1999 (year of a very strong year-class). From 1973 to 1999, the fluctuations in the condition factor follow the trend in the minimum temperature of the CIL (Fig. 8). After 1999, however, the 2 series seems unrelated.



PERIODE	CIF vs K r^2
1973-1999	0.84
1973-2000	0.81
1973-2001	0.80
1973-2002	0.79
1973-2003	0.78
1973-2004	0.77
1973-2005	0.74

Figure 8. Scomber scombrus: Time series of Atlantic mackerel condition factor and the CIL minimum temperature in the Gulf of St. Lawrence since 1973. The table shows the parametric correlation coefficient between the 2 series up to the year 1999 and the decreasing relationship (diminishing correlation coefficients) after 1999. The horizontal line represents the mean condition for the entire period.

For the last 15 to 20 years, mean carapace length (CL) of multiparous females shrimp (females that have already spawned once) is declining in all sectors of the nGSL; however, the trend is stronger for the eastern stock (Esquiman Channel). The reduction in mean size seems limited the multiparous females portion of the populations, whereas no or weaker declining trends are observed in the maximum size of males and for the size of primiparous females (just after sex change) in the populations. These observations remained unexplained at the moment.

Late-summer macrozooplankton surveys at stations over a grid in the LSLE are carried on since 1994. An analysis of the residuals of the length-weight relationships for 2 Euphausiid species, *M. norvegica* and *T. raschi*, revealed significant interannual variability in the condition (weight-at-length) of both species with lower conditions observed in the mid 1990s before increasing to reach maximum values in 2003. The changes in condition in both species were significantly positively correlated with sea surface salinity in the LSLE.

Overall, this preliminary report suggests that the early 1990s were years of relatively poor growth and low condition for many species in the Gulf of St. Lawrence. The positive trends

observed in the condition factors since that period suggest that the ecological conditions have been improving in the Gulf system.

4.3 Trends in Condition of Atlantic Cod (*Gadus morhua*) from the Southern Labrador Shelf to the Grand Banks (NAFO Divs. 2J3KLNOPs)

G. Lilly presented a paper on this topic.

Data required for monitoring size-at-age and condition of cod have been collected during bottom-trawl surveys in the offshore of the Newfoundland and Labrador area since about 1978. An overview of sampling protocols, sample sizes, and observations is in preparation (Lilly 2007).

The collapse of the cod stock off southern Labrador and eastern Newfoundland included a dramatic reduction in size range, such that very few cod longer than 50 cm have been caught during offshore research bottom-trawl surveys. The low or nil catches of cod of medium and large size since the mid 1990s greatly limits the value of cod condition as a tool for assessing ecosystem health.

In preparation for the present meeting, scientists in the Newfoundland and Labrador area decided that, as a first step, they would compile time series of annual means of Fulton's condition (based on round weight) for groundfish sampled during autumn offshore bottom-trawl surveys in divs. 2J3KLNO. The data would be organized by species, division, gender, and length-group. Time series in this format were prepared for Atlantic cod and were used in the preliminary study presented by Koen-Alonso et al. (this meeting).

The purpose of the present paper was to provide an overview of some of the condition data that have been reviewed during annual assessment meetings for the divs. 2J3KL and 3Ps cod stocks.

Format of Information on Condition

Because changes in round weight may be influenced by changes in the weights of gonads and stomach contents, it is helpful to delete the weights of these entities when expressing condition. For review during assessment meetings for divs. 2J3KL and 3Ps cod, body or somatic condition was expressed as Fulton's condition factor:

$$K = (W/L^3)*100$$

where W is gutted (eviscerated) weight (g) and L is length (cm). In addition, the muscle mass of cod is very lean. The organ for lipid storage is the liver, and the size of the liver in relation to the size of the fish is a good measure of energy storage. It is therefore common for authors to present a separate index for liver alone. For review during assessment meetings, liver index (LI) was computed in a manner analogous to that of body condition:

$$LI = (LW/L^3)*100$$

where LW is liver weight (g).

Northern (2J3KL) Cod

The well-being of cod in the offshore of divs. 2J3KL has been monitored with both size-at-age and condition. The lengths-at-age and weights-at-age of cod sampled during autumn research surveys confirm the general pattern of a decline in the 1980s and early 1990s as observed in weights-at-age derived from the sampling of commercial catches (Lilly et al. 2006). The research survey data also illustrate that the changes varied with division (Fig. 9). There was a strong decline in Div. 2J and a lesser decline in Div. 3K. There appears to have been little or no decline in Div. 3L, but the paucity of sampling prior to 1985 makes it very difficult to determine whether there was a decline during the early 1980s as occurred in the other 2 divisions. Superimposed on the long-term decline are periods of quicker or slower growth associated with changes in temperature (Shelton et al. 1999).

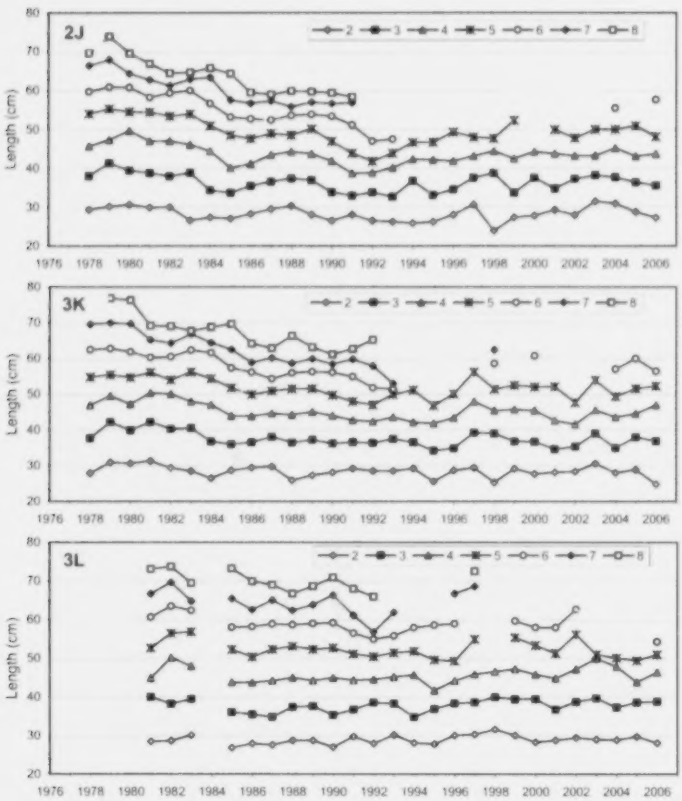


Figure 9. Mean length-at-ages 2-8 of cod in divs. 2J, 3K and 3L in 1978-2006, as determined from sampling during bottom-trawl surveys in autumn. Values calculated from fewer than 5 aged fish are not plotted. There were no surveys in Div. 3L during the autumns of 1978-1980 and 1984. (Updated from Lilly et al. 2006.)

The trend toward low mean size-at-age in the early 1990s was reversed during the late 1990s. In Div. 2J, where the decline was the greatest, recent mean lengths have been at or above the average for the period 1985-2006, but well below the levels of the early 1980s (Lilly et al. 2006).

Length-at-age has varied without consistent trend in the past few years. Much of the high year-to-year variability may be sampling error related to small sample sizes.

Trends in mean weights-at-age (not illustrated) were similar to those in lengths-at-age, but had additional variability related to changes in weight at length (condition).

Temporal changes in somatic condition-at-age (Fig. 10) and liver index-at-age (Fig. 11) varied among divisions. In Div. 2J, both gutted condition and liver index declined in the early 1990s. During the 2nd half of the 1990s, gutted condition returned almost to normal, whereas the liver index increased only a little. There has been variability with little trend since the mid 1990s. In Div. 3K, gutted condition declined during the early 1990s and improved during the latter half of the 1990s. Liver index changed little during the 1990s. As in Div. 2J, there has been variability with little trend since the mid 1990s. In Div. 3L, gutted condition has remained relatively unchanged over time. Liver index increased considerably during the early 1990s and has since returned to an intermediate level.

Because temporal patterns have differed between gutted condition and liver index, and among divisions within each of the 2 indices, it is difficult to summarize the trends in just a few words. It is also difficult to explain the different patterns (Lilly 2001). A study into the relationship between condition and annual variability in stomach contents, for the period 1978-1995, is in progress.

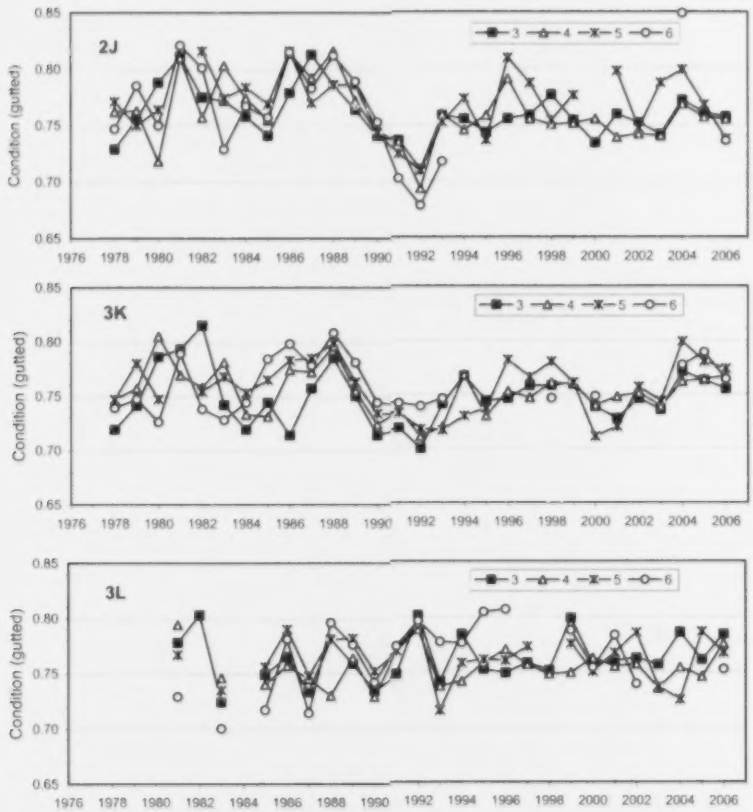


Figure 10. Mean Fulton's condition (gutted weight) at ages 3 to 6 of cod in divs. 2J, 3K, and 3L in 1978-2006, as determined from sampling during bottom-trawl surveys in autumn. Values calculated from fewer than 5 aged fish are not plotted. There were no surveys in Div. 3L during the autumns of 1978-1980 and 1984. (Updated from Lilly et al. 2006.)

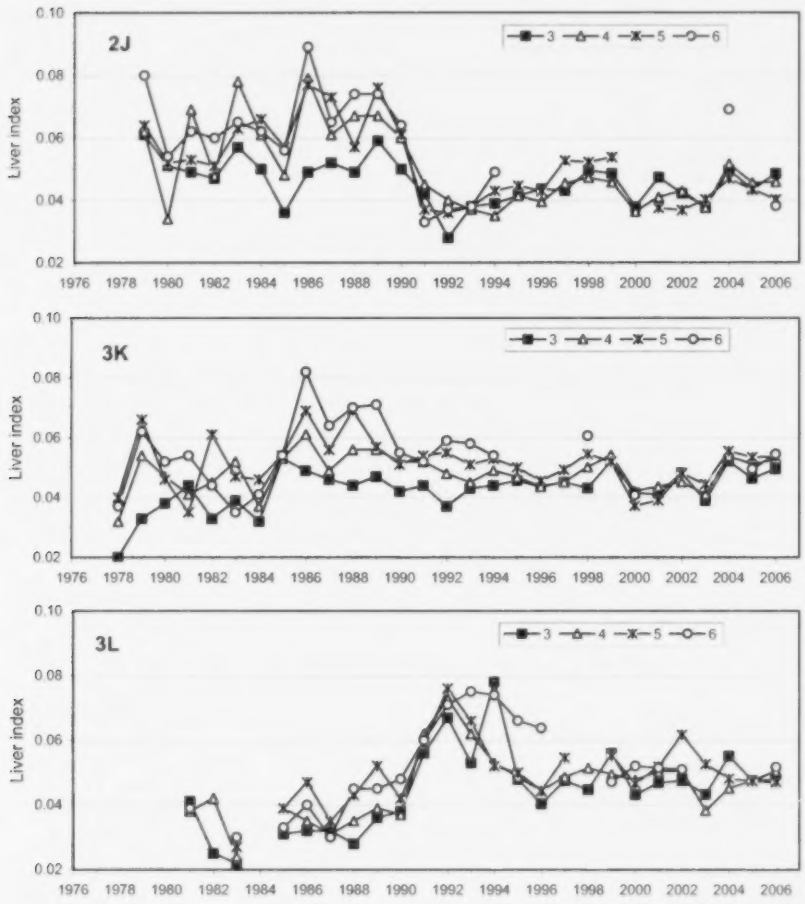


Figure 11. Mean liver index at ages 3 to 6 of cod in divs. 2J, 3K, and 3L in 1978-2006, as determined from sampling during bottom-trawl surveys in autumn. Values calculated from fewer than five aged fish are not plotted. There were no surveys in Div. 3L during the autumns of 1978-1980 and 1984. (Updated from Lilly et al. 2006.)

Southern Newfoundland (3Ps) Cod Stock

Trends in the condition of cod sampled during bottom-trawl surveys of Subdiv. 3Ps illustrate the potential of confounding that may be created by differences in survey timing. The timing of the Subdiv. 3Ps surveys has varied from February to June, with the bulk of the surveys prior to 1993 having occurred during winter (February-March), and all surveys since 1993 having occurred during spring (primarily April). If one were not aware of the changes in timing, one might conclude that somatic condition (Fig. 12) and liver index (Fig. 13) were relatively low during recent years. However, when timing is taken into account, it is clear that these low levels are mainly a consequence of sampling near the nadir of the annual cycle and are not necessarily indicative of a large and persistent decline in well-being. Nevertheless, it is apparent that there has been some annual variability within the recent (1993-2005) time period. Brattey et al. (2005) presented box plots of gutted condition and liver index by year for all cod in the length range 40 to 59 cm. For liver index, values tended to be high in 1998, 2003, and 2005 and low in

1999 and 2001. Reasons for these annual differences have not been investigated, but they are undoubtedly complex.

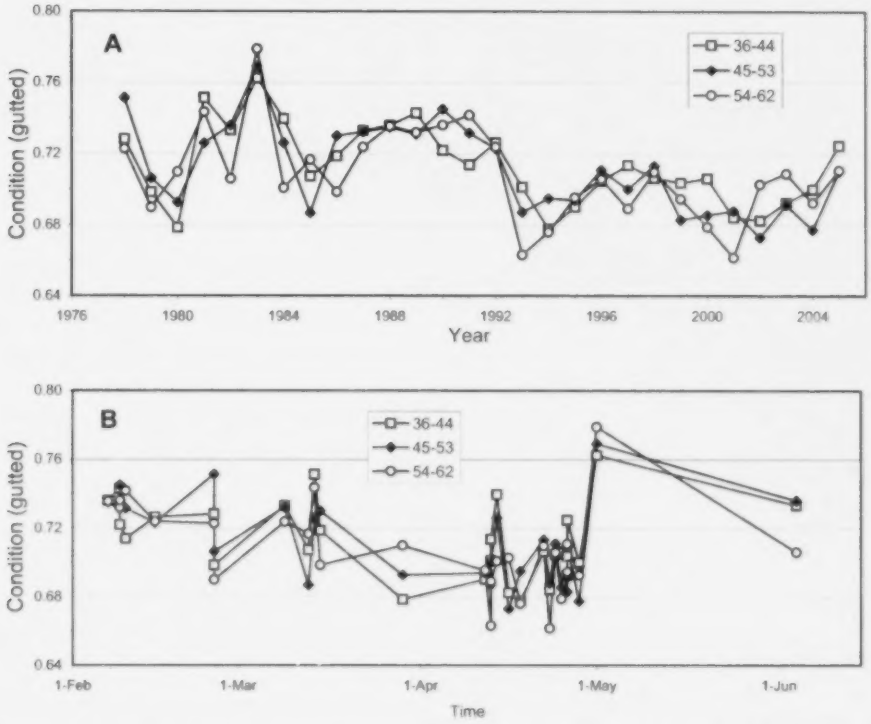


Figure 12. Mean Fulton's condition-(gutted weight)-at-length of cod in Subdiv. 3Ps in 1978-2005, as determined from sampling during bottom-trawl surveys in winter-spring. Panel A shows the data plotted by year, and Panel B shows the data plotted by median date of collection (from Brattey et al. 2005).

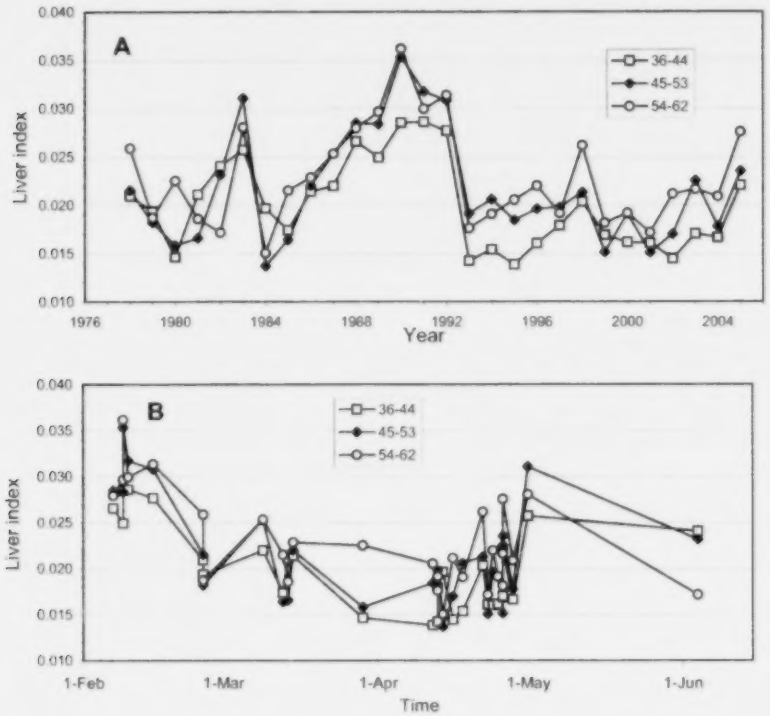


Figure 13. Mean liver index-at-length of cod in Subdiv. 3Ps in 1978-2005, as determined from sampling during bottom-trawl surveys in winter-spring. Panel A shows the data plotted by year, and Panel B shows the data plotted by median date of collection (from Brattey et al. 2005).

Long-term Changes

Some information on liver index, expressed as liver weight divided by body round weight, is available from the sampling of U.S.S.R. commercial catches in Div. 2J during many months in the period 1964-1966. When the mean values for autumn months are compared with values computed from samples taken during Canadian autumn surveys in the 1980s, it is apparent that the values from the 1960s are considerably higher. It is not known if this reflects a true decline in condition or an unrecognized difference in sampling method, location, or some other factor.

General Comments

When studying long-term changes in condition, it is necessary to account for differences in size of the fish and the timing of sampling. Exploratory analyses have also shown that it may be necessary to be aware of gender. Gutted condition appears not to differ consistently between genders, but liver index tends to be higher in females than in males. Gender differences in condition have not previously been considered during cod assessment meetings.

Various indices of well-being may not necessarily have the same pattern. Under such circumstances, how does one decide which indices should receive greater weight? Examples from the divs. 2J3KL cod stock follow:

i) The pattern in size-at-age may differ from the pattern in condition. For example, there was a decline in length-at-age of cod in divs. 2J and 3K from the late 1970s to the early 1990s; but somatic condition and liver index did not decline during the period from the late 1970s to about 1990. Indeed, liver index tended to increase during this period.

ii) Different measures of condition may show different trends. For example, within each of the divisions occupied by the 2J3KL cod stock, the temporal trend in somatic condition (gutted weight) tended to differ from that of liver index.

iii) Within a given stock, the pattern in a particular index may vary geographically. For example, the liver index of cod in Div. 2J declined during the early 1990s, whereas the liver index of cod in Div. 3L increased during the same period.

4.4 Trends in Condition of Pelagic Fish in Newfoundland Waters

F. Mowbray presented a paper on this topic (in collaboration with J. Carscadden and J. Wheeler as co-authors).

Investigations were made into temporal trends in the body condition of two pelagic species Atlantic herring (*Clupea harengus harengus*) and capelin (*Mallous villosus*).

Atlantic Herring

Atlantic herring were sampled from a spring research gillnet program operated in 4 different areas, 2 on the northeast coast of Newfoundland (White Bay /Notre Dame Bay and Bonavista Bay/Trinity Bay), and 2 on the south coast (St. Mary's Bay/Placentia Bay and Fortune Bay). The research gillnets consist of a fleet of 5 nets, 1 panel each of mesh sizes 50.8, 57.2, 63.5, 69.9, and 76.2 mm mesh, which are fished by contracted fishers during the spring of each year (DFO 2006). Fish caught include both spring and autumn spawners, but analysis of condition was limited to the better represented spring spawners. Data were available from 1988 to 2005 for the northeast coast stocks and from 1982 to 2005 for the south coast. As gillnets select for fish primarily by girth, potential bias in selectivity was a concern. For this reason, condition and GSI (Gonado-Somatic Index) were compared among mesh sizes. It was determined that the availability to the nets of poor-condition small fish and high-condition larger fish was affected by gillnet selectivity. Consequently, analysis was limited to 2 length groups of herring: medium (22 to 29 cm) and large (30 to 36 cm). Fulton's condition was calculated for each fish using total weight.

Visual inspection of the data revealed that trends in herring condition varied over time both within areas and among areas (Fig. 14). In White Bay/Notre Dame Bay, condition was lower in the early part of the time series and higher in recent years. In Bonavista Bay/Trinity Bay, a similar trend was seen for the smaller size class, though less markedly for the larger size fish. Herring condition for the south coast stocks tended to be stable and noisy, or show slight declines (e.g. small fish in Fortune Bay). Common to all 4 areas was a decrease in condition in the early 1990s. Research gillnet catch rates for the northern stocks were inversely related to condition, suggesting density dependence, while on the south coast condition tended to track catch rates (DFO 2006).

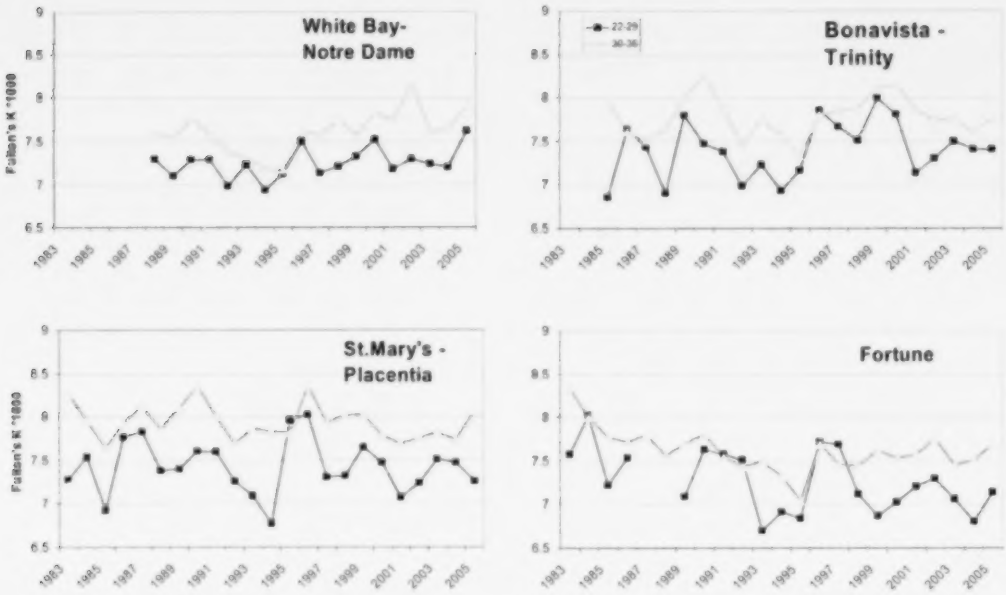


Figure 14. Trends in condition of large (triangles) and small (squares) Atlantic herring taken by research gillnets on the northeast coast (upper panels) and south coast (lower panels) of Newfoundland.

Capelin

Condition factors for capelin were calculated using data collected during 2 seasons, namely during spring (pre-spawning capelin) and during fall, when capelin are feeding. Capelin have exhibited marked changes in distribution and behaviour which have persisted since the early 1990s (Nakashima 1996; Carscadden et al. 1997; Carscadden and Nakashima 1997; Carscadden et al. 2001), and these changes had to be borne in mind in the estimation and interpretation of temporal changes of condition. For example, capelin channel energy from somatic tissues into gonads in the spring. This energy transfer occurs rapidly as exhibited by the rapid increase in roe content in the spring, and changes in this temporal transfer of energy should be taken into account when estimating the condition factors of pre-spawning capelin. In this analysis, the authors repeated the analysis of Carscadden and Frank (2002) by selecting only samples where the roe percent of females averaged 10% or greater. This approach was shown to isolate successfully capelin samples at the same point of their biological cycle, during a period when condition was at its peak and least variable (Fig. 15) (Carscadden and Frank 2002). Fulton's condition index for spring samples was calculated using somatic weight as opposed to whole weight, similar to the previous analysis by Carscadden and Frank (2002).

In contrast to the capelin captured in the spring, capelin sampled as bycatch in the fall bottom-trawl survey may be less affected by changes in spawning time, but are likely to be affected by changes in the vertical distribution and movement of capelin (Mowbray 2002). Moreover, a change in bottom-trawl fishing gear that occurred in the fall of 1995 may also have impacted on the size selectivity and catchability of capelin to the bottom-trawl survey. Capelin, and smaller fish in general, have been shown to be more strongly selected for by the Campelen trawl used since 1995, than the Engels trawl used prior (Warren 1995). Fulton's condition for fall samples was calculated using total body weight as gonad weight is negligible during this time of the year.

In each series, condition was calculated separately by sex and length class and for divs. 3L and 3K, and the condition factors from the 2 seasonal series were compared to identify common trends.

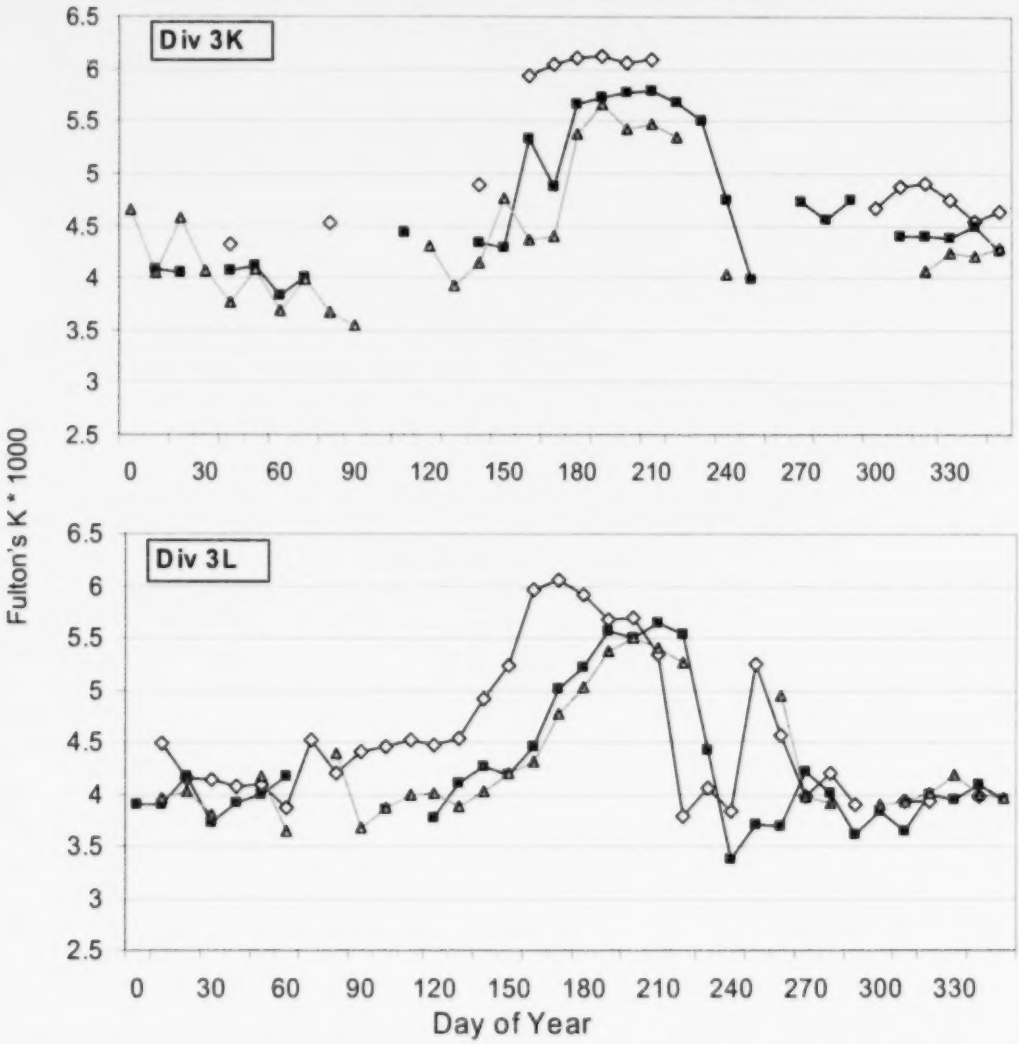


Figure 15. Annual cycle in the somatic condition of capelin in divs. 3L and 3K during 3 time periods: 1982-1990 (diamonds), 1991-1999 (squares), and 2000-2006 (triangles).

As reported by Carscadden and Frank (2002), spring capelin condition indices exhibited a long-term decline starting in early 1990s, persisting until the early 2000s. The analysis presented here, with the added data from the 2000s, indicates that there has been some recovery in condition during the last 4 years. This general trend appeared in both sexes, across size ranges and in both NAFO divisions (Fig. 16). However, while in Div. 3L capelin condition in recent years approaches values seen during the 1980s, most estimates for Div. 3K still remain below.

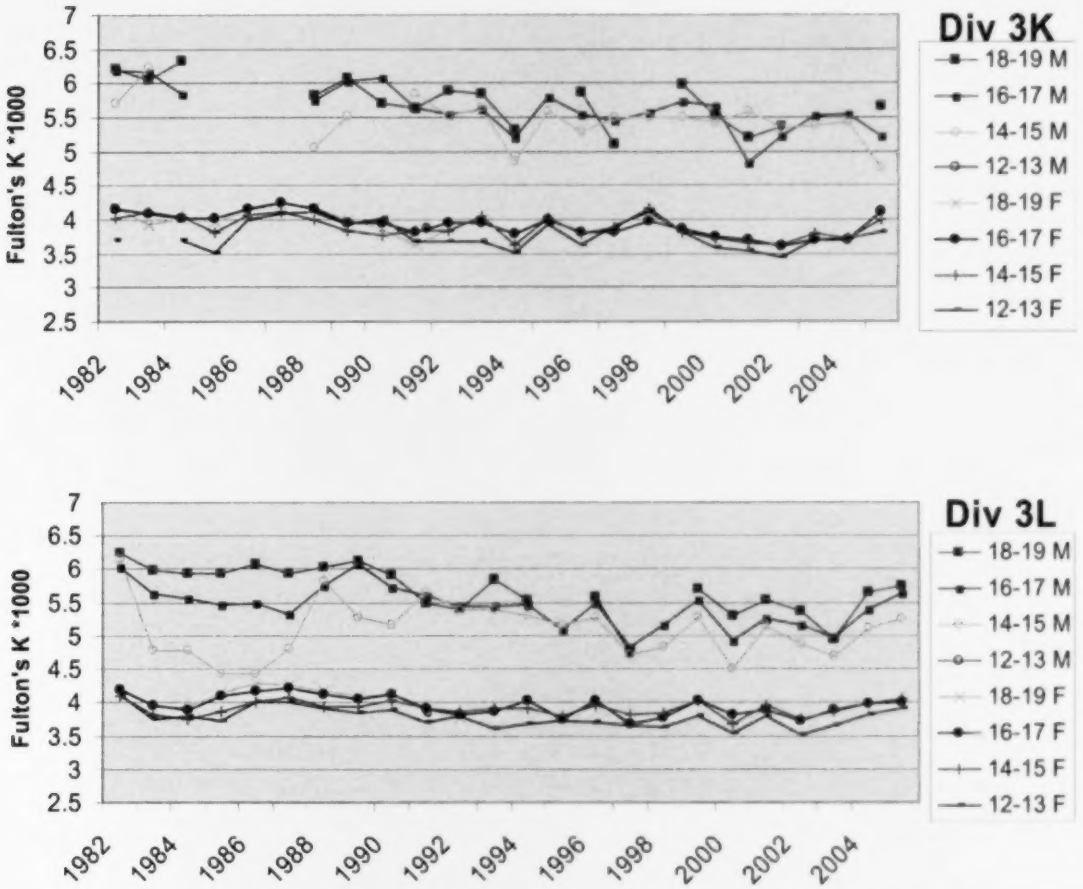


Figure 16. Somatic condition of male and female capelin from 12 to 19 cm sampled during the spring summer from NAFO divs. 3K and 3L.

Similarly, condition of capelin in fall Div. 3K surveys also declined during the early 1990s, although no consistent trend was observed in Div. 3L. It should be noted that sample size and availability was much poorer for the fall series, particularly for the years in which the Engels trawl was used, and in Div. 3L. This paucity of samples may be in part the explanation for the ambiguous results in Div. 3L (Fig. 17).

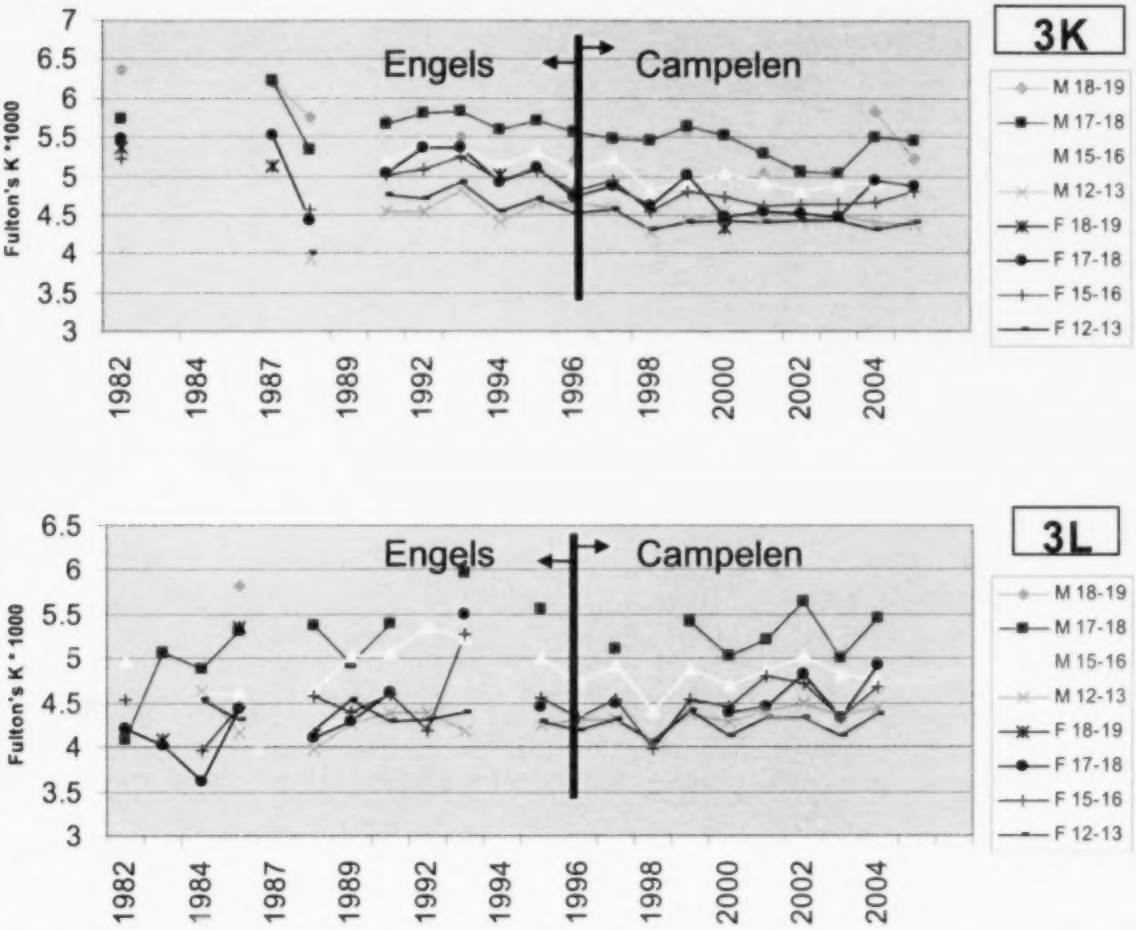


*Figure 17. Fulton's condition (*1000) of male and female capelin from 12 to 19 cm sampled during the spring and summer from NAFO divs. 3K and 3L.*

Comparing trends in capelin condition across seasons it was noted that the lower condition values, starting in the early 1990s, were more marked in the spring than in the fall. One interpretation of this result is that poor overall condition was to a greater degree driven by poor feeding conditions during the spring of the year. Declines in the stomach fullness of capelin during the spring, as well as reductions in the frequency of larger prey organisms, support this hypothesis (Mowbray, unpublished data).

4.5 Are there Common Trends in Condition Among Fish Species in the Newfoundland Shelf (NAFO Divs. 2J3KLNO)?

M. Koen-Alonso presented a paper on this topic (with G. Lilly, J. Morgan, F. Mowbray, and D. Power as co-authors).

It is well known that the Newfoundland shelf ecosystem (NAFO divs. 2J3KLNO) underwent significant changes in its community structure, being the most dramatic observed between 1985 and 1995. These changes involved collapses of several fish stocks, increase in crustaceans stocks, and significant changes in the biology of capelin, among others. In this context of

ecosystem change, the objectives of this analysis are to explore if there are identifiable trends in fish condition over time, to evaluate if these trends are consistent among fish species in this ecosystem, and whenever possible, to see if there is evidence of trends in condition during the period of dramatic ecosystem change. The species, period of time, season, and NAFO division considered for the analyses are detailed in Table 1.

Table 1. Schematic description of the time series constructed to analyze trends in condition among fish species in the Newfoundland shelf ecosystem.

Species	Period	Season	2J	3K	3L	3N	3O
Capelin	1982-2005	Fall	X	X	X		
Herring	1985-2005	Spring		X	X		
Cod	1977-2005	Fall	X	X	X	X	X
Plaice	1990-2004	Fall	X	X	X	X	X
Turbot	1990-2004	Fall	X	X	X	X	X
Redfish	1990-2004	Fall	X	X	X	X	X
Witch	1990-2004	Fall	X	X	X	X	X
Haddock	1990-2004	Fall				X	X
Yellowtail	1990-2004	Fall				X	X
Number of species considered per NAFO div.:			6	7	7	7	7

Condition was evaluated using the Fulton index (K) which is calculated as $K=W/TL^3$, where K is the Fulton index, W is the individual weight, and TL is the total length of the fish. Because K is not independent of length and after several exploratory analyses, the final K used for the exploration of common trends was the simple average of K values obtained for TL classes defined for each species in each NAFO division. Only 5 of the 9 species with available data were present in all NAFO divisions (cod, American plaice, turbot, redfish, and witch flounder), while 2 of them were present in the northern area (capelin and herring), and another 2 were only present in the southern Grand Bank (haddock and yellowtail flounder) (Table 1).

The existence of common signals among species was explored using Minimum/Maximum Autocorrelation Analysis (MAFA) (Solow 1994; Zuur et al. 2007), based on normalized time series of condition. The initial analysis was performed by NAFO divisions, and all species in each of them were considered. This first analysis covered the period 1990-2004.

Further explorations considering only common species among all NAFO divisions were also done using MAFA and Multidimensional Scaling (MDS), while some differences among groups were evaluated using Analysis of Similarities (ANOSIM) (Clarke and Warwick 2001).

Finally, additional species-specific explorations using MAFA and considering TL classes were carried out for those species with extended time series (cod, capelin, and herring).

All NAFO divisions but Div. 3L showed significant common signals in condition. The trends associated with these signals were not homogenous among species. Some of the species driving these patterns tend to be more associated with northern (e.g. capelin) or southern (e.g. yellowtail) regions, but there are also species widely distributed that showed clear trends (e.g. American plaice) (Fig. 18).

More specifically, witch flounder and redfish had declining trends in condition in Div. 2J, while American plaice had a positive trend in the same division. In Div. 3K, herring and American plaice showed and increasing trend in condition, while capelin condition clearly declined. Div. 3L did not show any significant common signal among species, even though individual species like American plaice and herring had significant and positive trends in condition. Yellowtail flounder

showed significant declines in condition in both divs. 3N and 3O, while American plaice had a declining trend in Div. 3N and showed an oscillatory pattern in Div. 3O where its condition increased in 1990-1994, then declined until 1999 and showed an increasing trend after that.

As a general working hypothesis, there appear to be 2 underlying patterns that drive changes in condition, one in the north and another in the south. 3L is a sort of "mixing area". To explore further this hypothesis, a restricted MAFA analysis was performed considering only common species (i.e. those that are present in all 5 NAFO divisions).

Surprisingly, the MAFA results considering only common species was unable of detecting any significant common trend in any NAFO division; but the simple observation of the normalized condition time series appears to show some commonalities among species. This suggests that the lack of significance could be more associated to a low signal-to-noise ratio than to an actual absence of signal. For this reason, a MDS plot based on the Bray-Curtis index was produce to explore further these condition time series.

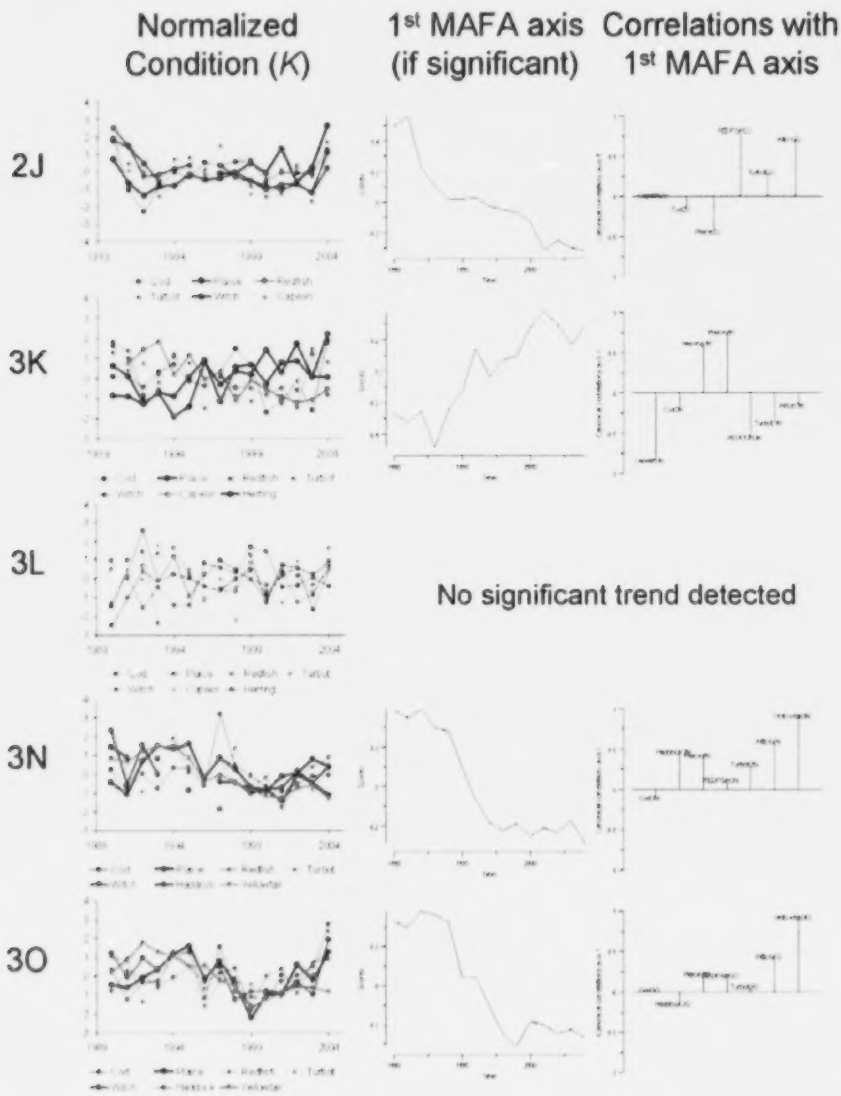


Figure 18. Results of the analysis of condition per NAFO division using MAFA. Left graphs: normalized condition time series. Center graphs: first MAFA axes (if it is statistically significant). Right graphs: canonical correlation between the first MAFA axis and the condition time series of each species. (Note that positive correlations indicate that the trend for the species is similar to the MAFA axis, while negative correlations indicate that condition follows a trend opposite to the one depicted by the MAFA axis.)

Although the stress of the MDS plot was high (stress=0.23), suggesting that the bidimensional plot was not fully representative of the relationships among series, it still shows clearly that species from the same NAFO division appear closer in their condition trends than a given species among NAFO divisions (Fig. 19). This observation was confirmed using a 2-way ANOSIM test considering NAFO division and species as factors. The results indicated that there were no significant differences among species (R=0.09, p-value=0.209), but the differences among NAFO divisions were significant (R=0.291, p-value=0.015). Along this line of inquiry, the

existence of trends over time was explored further by grouping years in 3 blocks (1990-1994, 1995-1999, and 2000-2004) and conducting a one-way ANOSIM test. The differences among blocks of time were highly significant (R=0.225, p-value=0.007), and pairwise comparisons indicated that consecutive blocks of time were marginally non-significant (1990-1994 versus 1995-1999: p-value=0.056; 1994-1999 versus 00-04: p-value=0.063), but the 2 extreme blocks of years were marginally significant (1990-1994 versus 2000-2004: p-value=0.048). These results strongly suggest a change of condition over time.

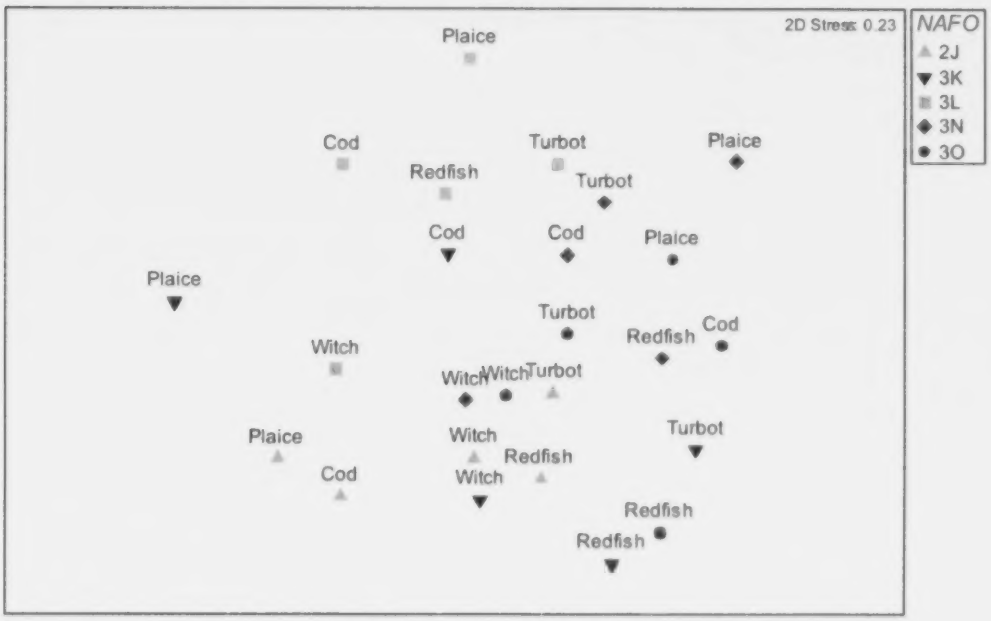


Figure 19. MDS plot based on a Bray-Curtis distance matrix of normalized time series of condition of species in each NAFO division. Normalized K values were transformed to K+6 to avoid negative values and be able of calculating the Bray-Curtis index.

Although all these results indicate changes of condition over time, and with some internal consistency within each NAFO division, the period analyzed starts in 1990; and some of the major changes in the Newfoundland ecosystem occurred between the late 1980s and the early 1990s. Therefore, it is likely that many major changes will not be captured by these analyses. There are early data available to calculate condition for only few species (cod, capelin, and herring), and even for these species the period covered is not consistent among them. These issues certainly hinder any possibility of generalizing trends in condition, but the analysis of each case is still helpful. Using MAFA and the condition time series for the *TL* classes defined for these species, it becomes clear that condition in cod declined significantly from the 1980s to the 1990s in divs. 2J and 3K. Capelin, at least in Div. 3K, also shows a consistent decline in condition, while herring apparently has the opposite trend, showing an increase in condition in Div. 3K (Fig. 20).

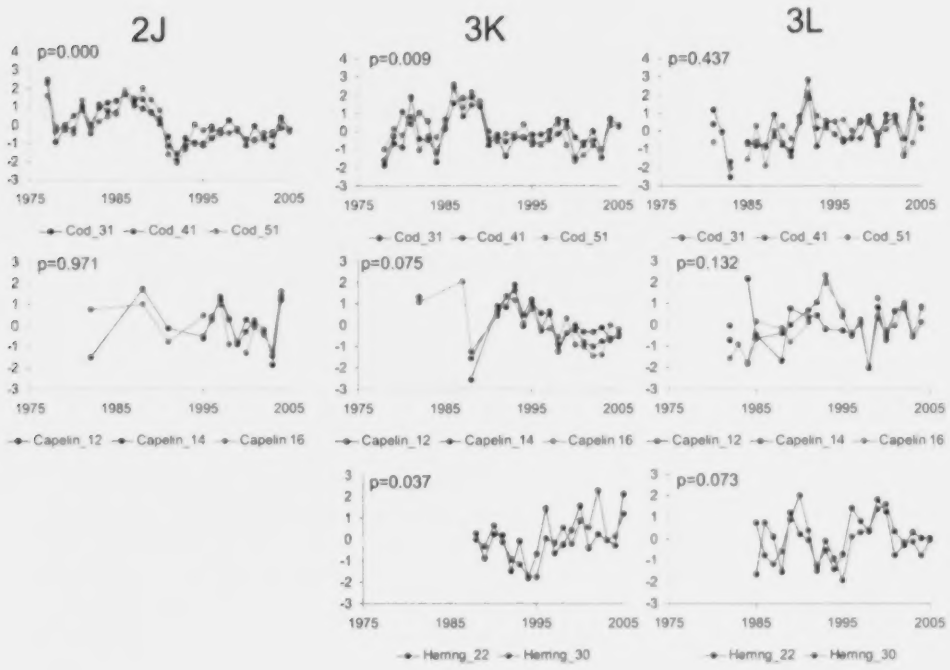


Figure 20. Normalized condition trends for cod (first row), capelin (second row), and herring (third row). Each series correspond to a TL size class and the numbers in the legends indicate the TL in cm at the beginning of the size interval. The indicated p-value corresponds to the significance of the first MAFA axis. In the case of capelin in Div. 3K, auxiliary analyses confirmed the significance of the common signal.

As concluding remarks, it is clear that there have been changes in condition over time during the period 1990 to 2004. These changes have a latitudinal pattern, being divs. 2J and 3NO the regions where they are more evident.

It is unknown if these changes have a single underlying driver (i.e. north and south are just extremes), or if there are different drivers acting in northern and southern regions.

There is no simple consistent pattern of change in condition among or within species. Within pelagics (e.g. capelin and herring in Div. 3K) and demersals (e.g. plaice and witch in Div. 2J) species have shown opposite trends, and this also happened within species (e.g. plaice in divs. 3K and 3N).

Although condition shows trends in the period 1990 to 2004, the evidence from cod indicates that this species suffered a major decline in condition in divs. 2J and 3K between the 1980s and 1990s. It is difficult to extrapolate what this implies at the system level, but it is fair to assume that the condition levels observed in the early 1990s do not reflect the conditions in the previous decade.

4.6 Notes on Condition of Two Auk Species, Atlantic Puffin and Common Murre, at Funk Island, Newfoundland

A paper (authored by B. Montevecchi, C. Burke, G. Davoren, and M. Koen-Alonso) was presented by M. Koen-Alonso.

Clarification

The original talk under this title involved the presentation of available information on condition of Atlantic puffin and common murres from Funk Island, Newfoundland, and the exploration of potential common trends between these species.

After the meeting, and while preparing this abstract, some issues were found with the common murre database used for the analysis which made the results presented for this species unreliable and the subsequent comparison with Atlantic puffin. Work is currently ongoing to address these issues. The present abstract will only describe the results on Atlantic puffin.

Extended Abstract

Within the framework of current work by FOC, and specifically regarding the exploration of trends in condition over time among different ecosystem components, the objective of this work is to describe briefly the trend in condition of Atlantic puffin from the Funk Island colony.

The basic data used for this description are information on wing length (*WL*) and total weight (*W*) of chicks collected during the reproductive season. Some early data are available for 1982 to 1984, but the bulk of the data correspond to the period 1991 to 2006.

The data analyzed correspond to chicks up to 115 mm of *WL*.

The relationship between *WL* and *W* is not linear, but it is common to use the ratio *W* / *WL* as an index of condition if the data used are constrained to a range of *WL* where the relationship between these variables is linear.

However, the analysis explored here actually considered the nonlinearity of the *W*-*WL* relationship; and it relied on calculating a relative condition index (C_{rel}). This index was based on the deviations from the expected value from a non-linear model fitted to the individual *W*-*WL* data.

The model used to obtain a predicted *W* was:

$$W = \frac{K(WL - L_0)}{a + (WL - L_0)} + \varepsilon$$

where *K*, L_0, and *a* are model parameters, and ε is a normally distributed error. This model was fitted using a maximum likelihood method.

Then, the value of C_{rel} for each bird was calculated as $C_{rel} = W_{obs} / W_{pred}$. Values of $C_{rel} > 1$ indicate conditions higher than expected, while the opposite occurs with $C_{rel} < 1$. The annual average of C_{rel} was used as condition index for that year. The time series of condition was normalized.

The non-linear model fit the *W-WL* data well (Fig. 21). When these data are used to calculate relative condition, an interesting pattern emerges. Between 1991 and 2004, there is a clear and positive trend in Atlantic puffin condition (Fig. 21). However, only the C_{rel} for 2004 appears higher than the C_{rel} for 1982. This observation suggests that Atlantic puffin condition may have declined in the 1980s. If this is the case, the positive trend observed recently may imply more of a recovery from a hindered state than an actual improvement in condition.

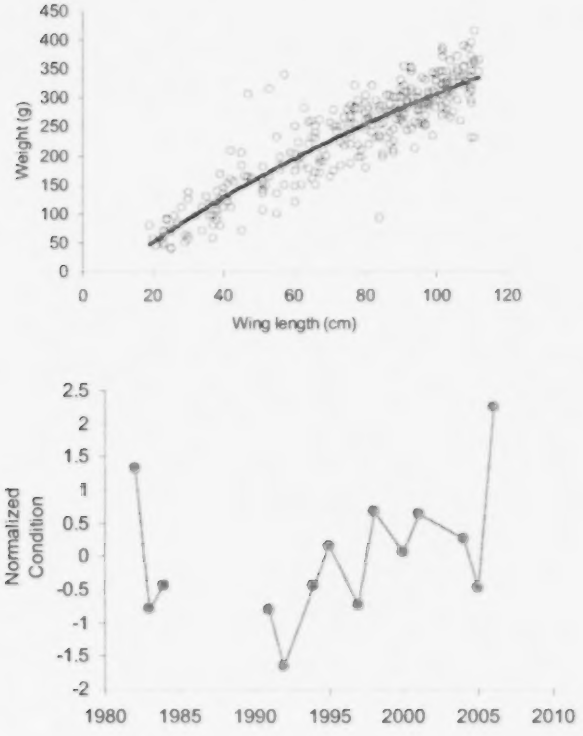


Figure 21. Top: Model fit to the Atlantic puffin weight-wing length data. Bottom: Normalized condition over time for Atlantic puffin chicks from the Funk Island colony.

4.7 Condition of Harp and Hooded Seals, Seasonal and Density Effects

A paper on this topic was presented by D. Chabot (with co-authors G.B. Stenson and F.O. Kapel).

Introduction

The harp seal (*Pagophilus groenlandicus*) and hooded seal (*Cystophora cristata*) are the 2 most abundant and pinniped species in the northwest Atlantic. Their populations were recently estimated to 5.82 million (Hammill and Stenson 2005) and 0.55 million animals (Hammill and Stenson 2006, excluding animals from the Davis Strait, which have not been surveyed in recent years), respectively. Moreover, abundance of these 2 species has changed radically over time. Hence, hunting pressure brought the harp seal population down to an estimated 2 million animals in the early 1970s. Changes in hunting regulations have resulted in a progressive increase in population size, which reached 4 million animals in the early 1990s and stabilized at

around present levels in 1996. Similarly, abundance of the northwest Atlantic hooded seal population was relatively low, hovering around 0.38 million to 0.4 million animals from the early 1960s until the mid 1980s. Then this population increased to about 0.45 million in the early 1990s and continued to increase by another 0.1 million animals during the 1990s and early 2000s (Hammill and Stenson 2006).

Thus, these populations are characterised by high and still-increasing abundance levels in the early 1990s, when many northwest Atlantic stocks of demersal fish on which they prey collapsed. The objectives of this study is to uncover possible density-dependent effects on harp and hooded seals by comparing growth and condition in the late 1970s and the 1980s to condition in the 1990s and early 2000s.

Materials and Methods

Data Collection: Harp (n=13555) and hooded (n=1638) seals were sampled off the coast of Labrador and Newfoundland in winter and spring of 1979 to 2006. Seals were collected by DFO researchers, commercial sealers, or as incidental catch in fishing gear. All animals were taken under a commercial or scientific permit and recorded as part of the total removals for the species. The majority of seals were shot and measured in the field; but samples from the Labrador coast (November to December) were caught in gillnets, frozen, and thawed before measurements were taken. Date, time, location, sex, and pelage condition (hair loose or fast, determined by pulling on clumps of hair) were noted. Standard length (L, to the nearest 0.5 cm), total mass (Mt, to the nearest kg for large animals and to the nearest 0.5 kg for smaller seals), axillary girth (G, to the nearest 0.5 cm), and blubber thickness (B, to the nearest 0.1 cm) were measured following the recommendations of the American Society of Mammalogists (1967), except that B excluded the skin. Mt was corrected for the mass of the stomach content, but not for blood loss in shot animals. The skin and blubber were removed together and weighed (Ms, to the nearest 0.5 kg). Core mass (Mc) was calculated as the difference between Mt and Ms. Age was determined by counting dentinal annuli from a cross-section of a lower canine tooth (Bowen et al. 1983) and assuming harp seals were born on March 5th and hooded seals on March 20th.

Additional harp seals collected in the Gulf of St. Lawrence between 1976 and 1979 by D.M. Lavigne (n=203) and between 1988 and 1992 by M.O. Hammill (n=437) were added to the authors' samples. Additional hooded seals were collected off the western and eastern coast of Greenland in summer of 1976 to 1991 by F.O. Kapel (n=153). Additional samples were collected following the same techniques as the authors' samples. A categorical variable, Decad, was set to 1980s and 1990s for seals sampled before 1990 and during or later than 1990 respectively.

Following McLaren (1993), all pups (<4 months old) except newborn seals were excluded because of the rapid changes in size taking place during lactation and the post-weaning fast. Measurement errors are possible given the conditions under which measurements are taken (on the ice, on moving boats, etc.); and tests were performed to detect improbable (standardized residuals <-4 or >4) combinations of length, Mt, Ms, G, and B (see Chabot and Stenson 2002). This resulted in the exclusion of 43 harp seals and 15 hooded seals. Furthermore, seals with a missing value for date of sampling, age, L, Mt, Ms, G, or B were excluded.

A total of 10,377 seals was retained for analyses. Table 1 gives the number of seals sampled each year according to species and sex. These numbers include 72 newborn harp seals and 18 newborn hooded seals. These were excluded from growth or condition analyses because

their body shape is different from that of older seals (they have little or no blubber), but were kept for a comparison of the size of newborn seals in the 1980s versus the 1990s.

Because of the large seasonal fluctuations in size and condition that characterize harp and hooded seals, data were subdivided into short (1-3 week duration) periods for harp seals (Chabot and Stenson 2002). Two periods are of interest in this paper: pre-reproduction (February 12th to March 4th) when harp seals are in best condition, and late-moult (April 23rd to April 29th) when they are very thin.

Smaller sample sizes made it necessary to use much coarser time periods for hooded seals (Leblanc 2003, Chabot et al. 2006). The only period when sample sizes permit comparison of growth or condition between the 1980s and 1990s is the reproduction pericd (March 13th to March 30th).

Growth Curves: Growth curves were computed for Mt, Ms, Mc, G, and L using the reparameterization of the Gompertz curve of M.C.S. Kingsley described in Hammill et al. 1995:

$$Size = S_\infty \bullet \left(\frac{S_0}{S_\infty}\right)^{e^{\left(\frac{K_0 e^{A_{SEX}}}{S_\infty \ln\left(\frac{S_0}{S_\infty}\right)}\right)}}$$

where S_∞ is asymptotic size, S_0 is size at birth, and K_0 is growth rate at birth. These curves were fitted to the data using the NLIN procedure of SAS (SAS Institute Inc. 1989).

For each species, sex, and period, growth curves for the 1980s and 1990s were compared statistically using the method described in Chabot and Stenson (2002).

Condition Indices: The 3 main condition indices assess general, sculp, and core condition respectively, by comparing measured Mt (or Ms or Mc) to Mt predicted from length according to an allometric relationship computed with the authors' own data. Many allometric relationships were investigated and compared in the Addition I and Addition II sections below. In the case of harp seals, the condition indices adopted to compare condition in the 1980s and 1990s were based on allometric relationships established with lean seals (late-moult period). There were not enough data available for lean hooded seals; condition indices were computed using allometric relationships based on all available data. Other condition indices were computed: Smirnov's condition index (G*100/L) (Smirnov 1924), Fulton's condition (Mt*10000000/Length^3), the sculp ratio (Ms/Mt), and blubber thickness (B). None of these additional indices proved more useful than our general, sculp, and core condition indices.

Statistical Procedures: Trends in the behaviour of residuals or condition indices were investigated with non-parametric smoothers (lowess, span=2/3) (R Development Core Team 2007). Lack of linearity in linear regressions was tested with the Harvey Collier test (Harvey and Collier 1977) using the R package *lmtest* (Zeileis and Hothorn 2007). The inflection point (breakpoint) in relationships that were deemed non-linear was calculated with R package *segmented* (Muggeo 2004). Comparisons of condition indices between the 1980s and 1990s were made with 2-way ANOVAs (Decad x Sex) or 2-way ANCOVAs (Decad X Sex, Age as covariate) using JMP (SAS Institute Inc. 2003).

Results

Growth: Growth curves for male harp seals sampled during the pre-reproduction period, and for female harp seals sampled in the late-moult period are shown in figs. 22 and 23. Data for the 1980s and the 1990s were fitted separately. These show size-at-age; and clearly, variables that were expected to be influenced by nutritional status (total, sculp and core mass, as well as girth) reached higher values during the 1980s than during the 1990s. In almost all cases, asymptotic size was significantly greater in the early years than in the recent years (Table 2); and in the few cases when the difference was not significant another parameter usually was, indicating that very young harps seals were larger at age and/or were gaining size more quickly with age during the 1980s than during the 1990s.

The authors did not expect significant differences in length, because final size was reached at 8 to 10 years according to the growth curves. Therefore, final length was reached during the 1980s for many of the older seals, even though they were sampled in the 1990s. However, asymptotic length was shorter in the 1990s relative to the 1980s for both sexes of harp seals during the late-moult period; but this may be the result of the small number of old seals sampled at this time of year (see Fig. 23). A more appropriate technique to test for a reduction in growth rate for length is to concentrate on the first few years of life, when growth in length is taking place (e.g. first 5 years). Chabot et al. (1996, p. 28-30) did this and found that young harp seals were significantly shorter at age in the 1990s than in the 1980s.

The evidence for density-dependent effects on harp seals was overwhelming: growth curves for Mt, Ms, Mc, and G of seals sampled during the 1990s were always below those calculated during the 1980s. In fact S_∞ for Mt, Ms, Mc, and G was always significantly lower during the 1990s than during the 1980s, except for Ms of male harp seals during pre-reproduction (Table 2). The 2 other parameters of the growth curves often differed significantly as well; and when they did, S_0 and K_0 were always lower for the 1990s than for the 1980s.

For hooded seals, smaller sample sizes permitted only the comparison of growth curves between the 1980s and 1990s for females during the reproduction period; and even in this case, the relationships between size and age were noisy and sample size was particularly small for the 1990s (Fig. 24). A significant drop in S_∞ for Ms and G was observed between the 1980s and the 1990s. The lack of data on young hooded seals made it necessary to include newborn seals in the computation of growth curves. As a result, no emphasis is placed on the comparison of the S_0 and K_0 parameters.

A further problem when comparing growth and condition of hooded seals during the reproduction period is that mass and energy reserves are known to change quickly during whelping, and this may have influenced the authors' results. For instance, if female hooded seals were sampled a few days earlier, on average, during the 1980s, larger size-at-age for the 1980s could be the result of a smaller proportion of females having given birth or completed lactation (which lasts only 4 days in this species). Fig. 25 shows that the median sampling date was the same for the 1980s and the 1990s (Day 84, March 25th) when all female hooded seals were considered, and also when only females ≥10 years were considered, these being the most influential animals in the calculation of S_∞. There remains the possibility that differences in environmental factors (e.g. ice conditions) may have delayed the median date of whelping in the 1980s compared with the 1990s, with the effect that even if seals were sampled at about the same dates in both time periods, seals from the 1980s would have been less advanced in their reproduction. The authors have not verified using meteorological records, but bad ice conditions seem to have been more frequent in recent years - not during early years. The drop in size-at-

age observed for Ms and G are probably not the result of differences in dates of sampling or in ice conditions.

Condition: At the FOC meeting in early April, the authors used Type II regressions to study allometric relationships between mass and length (both log-transformed) of seals. Condition indices were based on these relationships. The authors do not show these results here, even though they simply confirmed what the comparisons of growth curves have shown above (i.e. both seal species were in better condition during the 1980s than during the 1990s). Instead the authors show, in the Addition I section below, condition indices based on Type I regressions and present the authors' reasons for changing from Type I to Type II regression

Furthermore, the authors studied the impact of age and length on the seasonal cycle of energy accumulation and utilization in the Addition II section below to verify how they influenced allometric relationships and therefore how condition indices should be calculated and compared between seasons or between the 1980s and 1990s. For harp seals, the authors chose to calculate allometric relationships between mass and length of lean seals (data from late-moult only) (Addition II section below). There were insufficient data from lean hooded seals and allometric relationships were based on all available data.

Because harp seal condition indices used allometric relationships that were based on data from the late-moult period only, they were independent of length during the late-moult period and averaged one, as expected (Fig. 26 for male harps seals; results were similar for females and are not shown). However, seals sampled during the 1980s were in better general, sculp, and (to a lesser degree) core condition than those sampled during the 1990s. At this time of year, seals of all ages and sizes were negatively affected to a similar degree by the conditions prevailing during the 1990s.

Young and old harp seals displayed very different patterns of energy accumulation prior to the reproduction period (Fig. 27 for females; results were very similar for males and are not shown). All but the very young and very short harp seals were in much better condition at this time of the year than about 2 months later, during the late-moult period. But again, condition was better during the 1980s than during the 1990s, and the deterioration was similar for seals of all ages and lengths: the fitted lines are more or less parallel except near the end of the distributions, where small sample sizes resulted in strong but not very meaningful deviations (Fig. 27). However, a comparison of the condition indices in the 1980s and 1990s by ANOVA would likely be biased by differences in the proportions of young and old seals in both samples. For this reason, the authors chose to compare condition indices of harp seals between the 1980s and 1990s only for harp seals ≥9 years. Changes in condition of young harp seals was not tested here, but this could be done using age as a covariate in ANCOVAs.

Hooded seals were only studied during the reproduction period because sample sizes were too small during other periods. Condition indices were obviously much lower for newborn female hooded seals, as expected (Fig. 28) but did not differ with age for older animals. There did not seem to be any relationship between condition and age for male hooded seals (Fig. 29), except for newborns having a low condition, although the sample size could be responsible for this. There was no reason not to extend the ANOVAs on condition indices of hooded seals to all animals except newborns.

All ANOVAs comparing condition in the 1980s to that in the 1990s resulted in a non-significant interaction term. Sex was sometimes significant, but these results are not the focus of the present study and are not shown. In all ANOVAs except one, Decad had a significant impact on condition: all 3 forms of condition indices (general, sculp, and core) were greater during the

1980s than during the 1990s (Table 3). The exception was sculp condition of harp seals during the pre-reproduction period (P=0.059).

Conclusion

The authors compared growth (size-at-age) and condition (size-at-length) of harp and hooded seals in periods when they were less abundant and stocks of important prey species, demersal fish, were still abundant (the 1980s, effectively 1976 to 1989), and when seal abundance had increased considerably and at the same time, stocks of many demersal fish collapsed and, for the most part, did not recover (the 1990s, effectively 1990 to 2005). The results of the analyses are unequivocal: measures of size that were related to energy reserves (total, sculp and core mass, girth) and condition indices (also related to energy reserves) were all significantly reduced during the 1990s compared to the earlier time period.

In the case of harp seals, the comparisons were done at 2 different times during the seasonal cycle: prior to reproduction, when seals are fattest; and in late-moult, when they are leanest. Harps seals during the 1990s started their reproduction period and ended their moulting period in worse condition than harp seals during the 1980s, meaning that reproductive success as well as survival could be both compromised.

Hooded seal size and condition during the 1980s and 1990s could only be compared during the reproduction period, which is not the best time to do so because condition changes quickly at this time of year. Median sampling date was the same during the 1980s and 1990s, giving the authors some confidence that the drop in condition and size-at-age observed in the 1990s compared to that in the 1980s was not the result of sampling bias.

These results do not demonstrate a causal relationship between seal abundance and that of their food supply, because many other factors are known to have influenced the abundance of demersal fish stocks. They do suggest, however, that density-dependent effects are at play and that both seal species had more difficulty feeding effectively during the 1990s than during the 1980s because of the combine effects of a large seal biomass and depleted fish biomass.

Addition I: Type I and Type II Regression in Allometric Relationships

Before the FOC meeting of April 2007, the authors compared Type I and Type II regression to analyse the relationships between log-mass and log-length. The authors adopted Type II regression based on recommendations from several authors (e.g. Ricker 1973; Isobe et al. 1990; Sokal and Rohlf 1995; Warton et al. 2006). In allometric relationships, log-mass and log-length can be interchanged, i.e. there is no theoretical reason to view one as independent and the other as dependent variable. These authors argued that the functional relationship between the 2 variables was better described by Type II regression, where the slope is steeper than in Type I regression. The difference between these 2 slopes is inversely related to r^2 (and disappears when $r^2=1$). For example, to test if the allometric exponent for a species differed from 3, a common question for those interested in animal shape, Type II regression ought to be used.

There is debate about the use of Type II regression, and some of the same authors (e.g. Isobe et al. 1990; Sokal and Rohlf 1995) stated that when the goal is prediction of 1 variable from another and not the study of a functional relationship, Type I regression can be used. It is not clear if this means that Type I is preferable (should be used) or if Type II is not required, and thus Type I is acceptable.

For the authors' intended use, there are arguments in favour of both types of regression. Mass needs to be predicted from length to compute condition indices, for which Type I regression can be used. On the other hand, regression lines can be compared directly instead of using condition indices. This is a comparison of functional relationships, and Type II regressions should be used. The authors presented such analyses at the FOC meeting (one example is shown in Fig. 30), and overall these analyses led to the same conclusion that was reached by comparing growth curves for the 1980s and 1990s: male and female seals of both species had lower Mt, Ms, and Mc, for a given age/size, during the 1990s than during the 1980s.

Although r^2 were always high in such relationships, close examination of the residuals showed that there was an inflection point at logLeng ≈ 5, the slope being steeper for larger seals. Fig. 31 is another example, this time for male harp seals and for all seasons and years together. This change in slope affected the quality of both Type I and Type II fits, though Type I performed less well for large seals, and Type II for small seals.

The authors performed the Harvey-Collier test of linearity on the Type I relationship between Mt and Length (both log-transformed) for each sex and each species, using data from all seasons and years. There was a significant departure from linearity ($p<0.05$) for the 4 comparisons. With the *segmented* package, the authors calculated the inflection point (breakpoint) in these relationships (Table 5). Inflection points were similar for male and female harp seals (mean=5.043 on log scale, or 154.9 cm). Harp seals reach this length when about 5 years old, on average (figs. 22 and 23); and this sudden increase in the slope of the mass-length relationship is likely due to a large proportion of seals being involved in reproduction and large increases in mass and energy reserves related to reproduction.

Although inflection points were detected for hooded seal allometric relationships as well, the authors have less confidence in these findings because of the small sample sizes. The change in slope for larger animals was a decrease instead of an increase, and the authors have no biological explanation for this. Differences in date of sampling between seals of different lengths (say, a greater proportion of long hooded seals than short hooded seals sampled in post-reproduction or in Greenland, when seals are expected to be thinner) could have biased this analysis. This requires further study.

The presence of an inflection point and an increase in variance for larger seals (Fig. 32) convinced the authors to favour the use of condition indices instead of the direct comparison of regression lines to investigate density-dependent effects on harp and hooded seals.

Addition II: The Choice of Allometric Relationships Used in Condition Indices

At the FOC meeting, the authors used Type II regressions of Mt, Ms, and Mc to compute general, sculp, and core condition indices, respectively. These regressions were based on all available seals for a given sex and species (i.e. all seasons and years). These condition indices were still related to length, even though they were conceived to remove the effect of length. The presence of an inflection point (see Addition I section above) was partly responsible for this.

An inflection point in allometric relationships is not necessarily an obstacle for calculating condition indices that are independent of length. A non-linear fit or a segmented linear fit (i.e. 2 regressions end-to-end, 1 for smaller animals and 1 for larger animals) could be used instead of a simple linear regression. Fig. 33a shows such a fit for male harp seals, and Fig. 33b confirms that the general condition index computed from this segmented (Type I) regression was independent of length.

However, condition was independent of length only when all the data points used to compute the regression were represented on the plot of condition indices. Strong patterns were apparent in the residuals for specific subsamples of the data, such as seals from the pre-reproduction and late-moult periods (Fig. 33c), or from the 1980s and 1990s during the pre-reproduction period (Fig. 33d).

By studying regressions of Mt on Length (both log-transformed) for shorter time periods, it became clear that different patterns of energy gains and losses in small and large seals caused the inflection point in allometric relationships and prevented condition indices from being independent of length for some subsamples. Thus, a simple linear relationship fitted the data in late-moult well (Fig. 34) and produced condition indices that were independent of length. It was impossible, however, to obtain a satisfactory linear relationship between Mt and L for harp seals sampled during the pre-reproduction period (Fig. 35). As a result, condition indices calculated by forcing a linear relationship through these data were themselves related to length (Fig. 35c-d). Condition indices for this subsample have already been shown to be dependent on length when based on an allometric relationship that used data from all seasons (Fig. 33c). The authors opted to base all condition indices on allometric relationships fitted to data for the late-moult only (Fig. 35e-f), thus condition is relative to that of lean seals in the Results section above.

The main lesson from these analyses is that condition indices that rely on allometric relationships to remove the effect of length will rarely be independent of length for comparisons between subsets of the data (different seasons, years, etc.) or for new data; and care should be taken to base these comparisons on age- or size-classes where the indices are relatively independent age or size, unless the design is balanced and all samples have the same age or size distribution. The same applies to condition indices that do not rely on allometric relationships (Smirnov, Fulton, sculp ratio, etc.). This is shown in figs. 36 and 37 for the pre-reproduction and late-moult periods respectively.

Table 2. Sample size by year for harp and hooded seals.

Year	Harp Seals		Hooded Seals	
	F	M	F	M
1976	42	23	2	6
1977	16	25	0	0
1978	30	13	0	0
1979	225	147	1	0
1980	57	83	0	0
1981	269	310	1	0
1982	264	457	0	0
1983	333	270	13	4
1984	212	221	172	17
1985	1	1	229	18
1986	94	96	0	0
1987	103	183	0	0
1988	98	75	0	0
1989	140	169	2	3
1980s	1,884	2,073	420	48
1990	136	94	41	11
1991	81	90	13	16
1992	375	724	22	38
1993	159	163	5	16
1994	132	119	30	29
1995	111	154	0	0
1996	174	108	1	7
1997	71	50	3	5
1998	343	366	4	5
1999	163	81	1	4
2000	371	233	2	1
2001	97	93	3	3
2002	126	48	11	19
2003	118	55	5	4
2004	483	245	34	48
2005	0	0	1	7
1990s	2,940	2,623	176	213
Total:	4,824	4,696	596	261

*Table 3. Summary of growth curve comparisons between the 1980s and the 1990s for harp and hooded seals. * indicates a significant difference for a parameter of the growth curves (S_∞, S0 or K0).*

Species	Sex	Period	Variable	S_∞	S_0	K_0
Harp	M	Pre-	Mt	*	NS	*
			Ms	NS	*	*
			Mc	*	NS	*
			G	*	*	NS
			L	NS	NS	NS
		Late-moult	Mt	*	*	*
			Ms	*	*	*
			Mc	*	NS	*
			G	*	*	*
			L	*	*	NS
	F	Pre-	Mt	*	NS	*
			Ms	*	*	*
			Mc	*	NS	*
			G	*	*	NS
			L	NS	*	NS
		Late-moult	Mt	*	*	*
			Ms	*	*	*
			Mc	*	*	*
			G	*	*	NS
			L	*	*	NS
Hooded	F	Reproduction	Mt	NS	NS	*
			Ms	*	NS	NS
			Mc	NS	NS	NS
			G	*	NS	NS
			L	NS	NS	*

Table 4. Summary of 2-way ANOVAs (Decad x Sex) on condition indices of harp and hooded seals sampled during the 1980s and the 1990s. The interaction term was never significant. Sex was sometimes significant but this is of no interest here. Decad was significant and condition was always greater during the 1980s than the 1990s.

Species	Ages	Period	Condition index	F	d.f.	P	Decad	LS-Means	95% CI	
Harp	≥ 9	Pre-reproduction	General	26.2	[1, 394]	<.0001	1980s	1.434	1.401	1.466
							1990s	1.330	1.308	1.353
			Sculp	3.6	[1, 394]	0.059	1980s	1.430	1.392	1.468
							1990s	1.385	1.358	1.412
			Core	40.6	[1, 394]	<.0001	1980s	1.447	1.408	1.486
							1990s	1.293	1.266	1.320
		Late-moult	General	165.2	[1, 597]	<.0001	1980s	1.087	1.073	1.101
							1990s	0.971	0.960	0.982
			Sculp	15.8	[1, 597]	<.0001	1980s	1.130	1.111	1.149
							1990s	0.933	0.918	0.948
			Core	19.7	[1, 597]	<.0001	1980s	1.058	1.042	1.075
							1990s	1.012	0.999	1.025
Hooded	> 0	Reproduction	General	7.7	[1, 430]	0.0056	1980s	1.037	1.009	1.065
							1990s	0.955	0.904	1.006
			Sculp	6.9	[1, 430]	0.0091	1980s	1.054	1.014	1.094
							1990s	0.945	0.873	1.016
			Core	4.0	[1, 430]	0.0468	1980s	1.072	1.040	1.103
							1990s	1.006	0.950	1.063

Table 5. Inflection points in the regression of Mt on length (both log-transformed) of harp and hooded seals.

Species	Sex	Inflection Point	SE
Harp	Male	5.048	0.018
Harp	Female	5.039	0.015
Hooded	Male	5.101	0.087
Hooded	Female	5.211	0.076

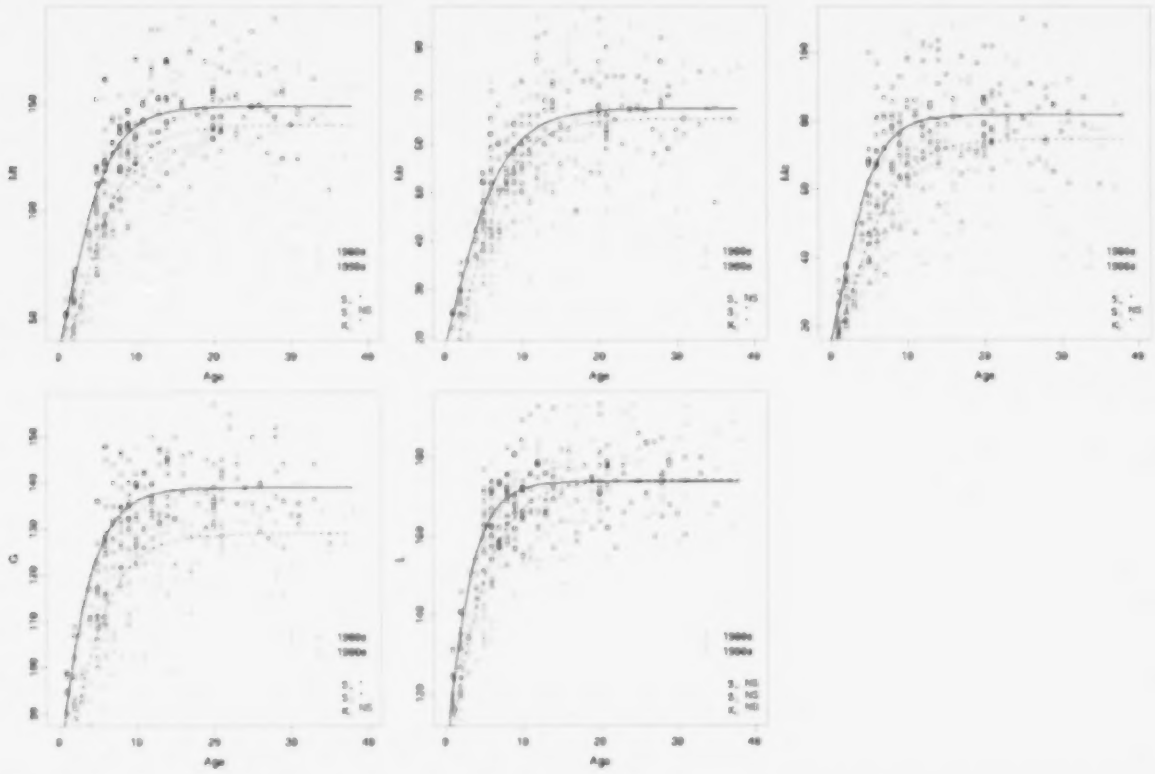


Figure 22. Growth (size-at-age) in total, sculp and carcass mass, in girth and in length of male harp seals during the pre-reproduction period. Data collected between 1976 and 1989 (1980s) and between 1990 and 2004 (1990s) were fitted separately. Significant differences in the parameters of the growth curves are indicated at the bottom right of each plot.

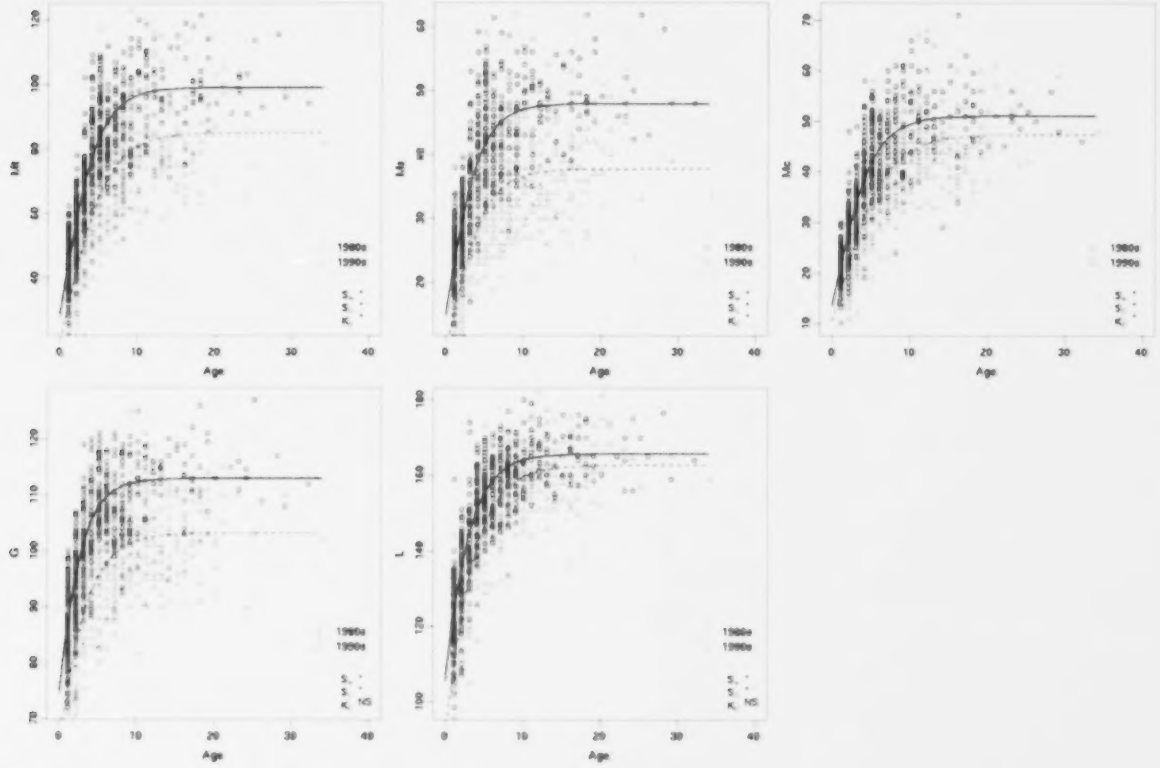


Figure 23. Growth (size-at-age) in total, sculp and carcass mass, in girth and in length of female harp seals during the late-moult period. Data collected between 1976 and 1989 (1980s) and between 1990 and 2004 (1990s) were fitted separately. Significant differences in the parameters of the growth curves are indicated at the bottom right of each plot.

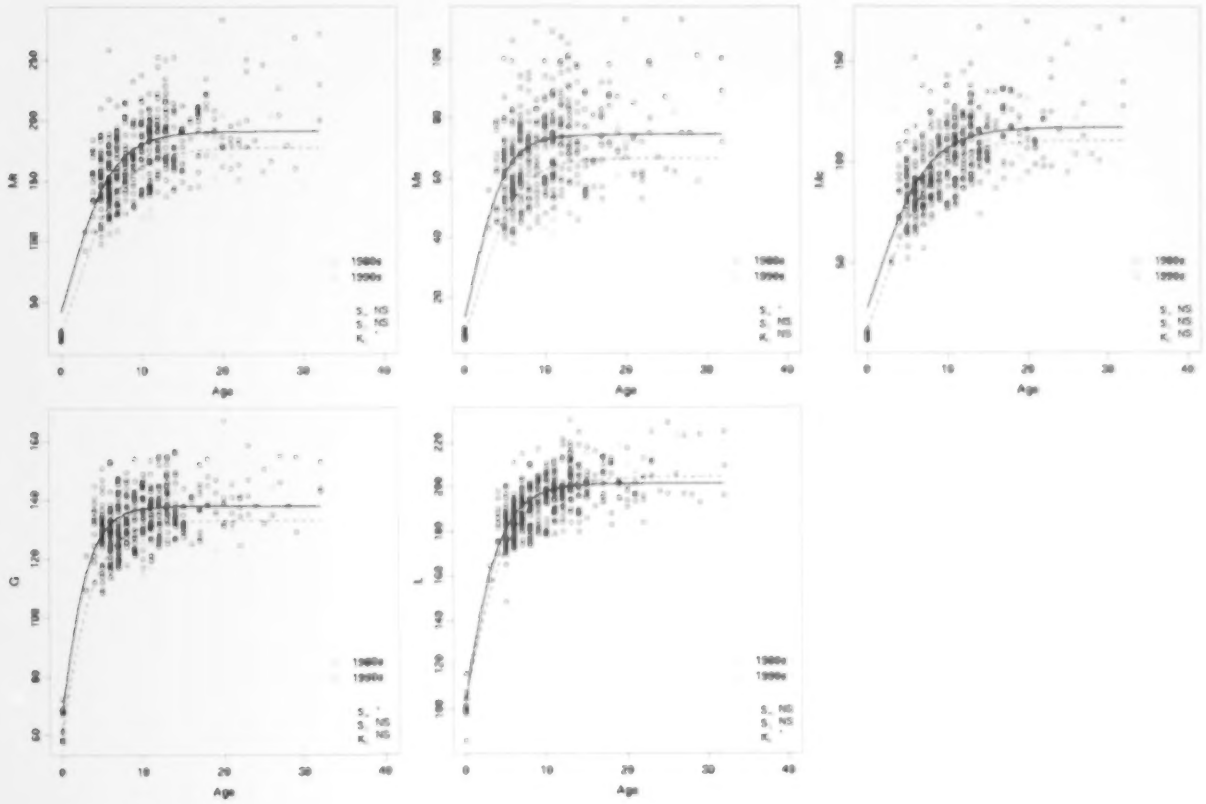


Figure 24. Growth (size-at-age) in total, sculp and carcass mass, in girth and in length of female hooded seals during the reproduction period. Data collected between 1976 and 1989 (1980s) and between 1990 and 2005 (1990s) were fitted separately. Significant differences in the parameters of the growth curves are indicated at the bottom right of each plot.

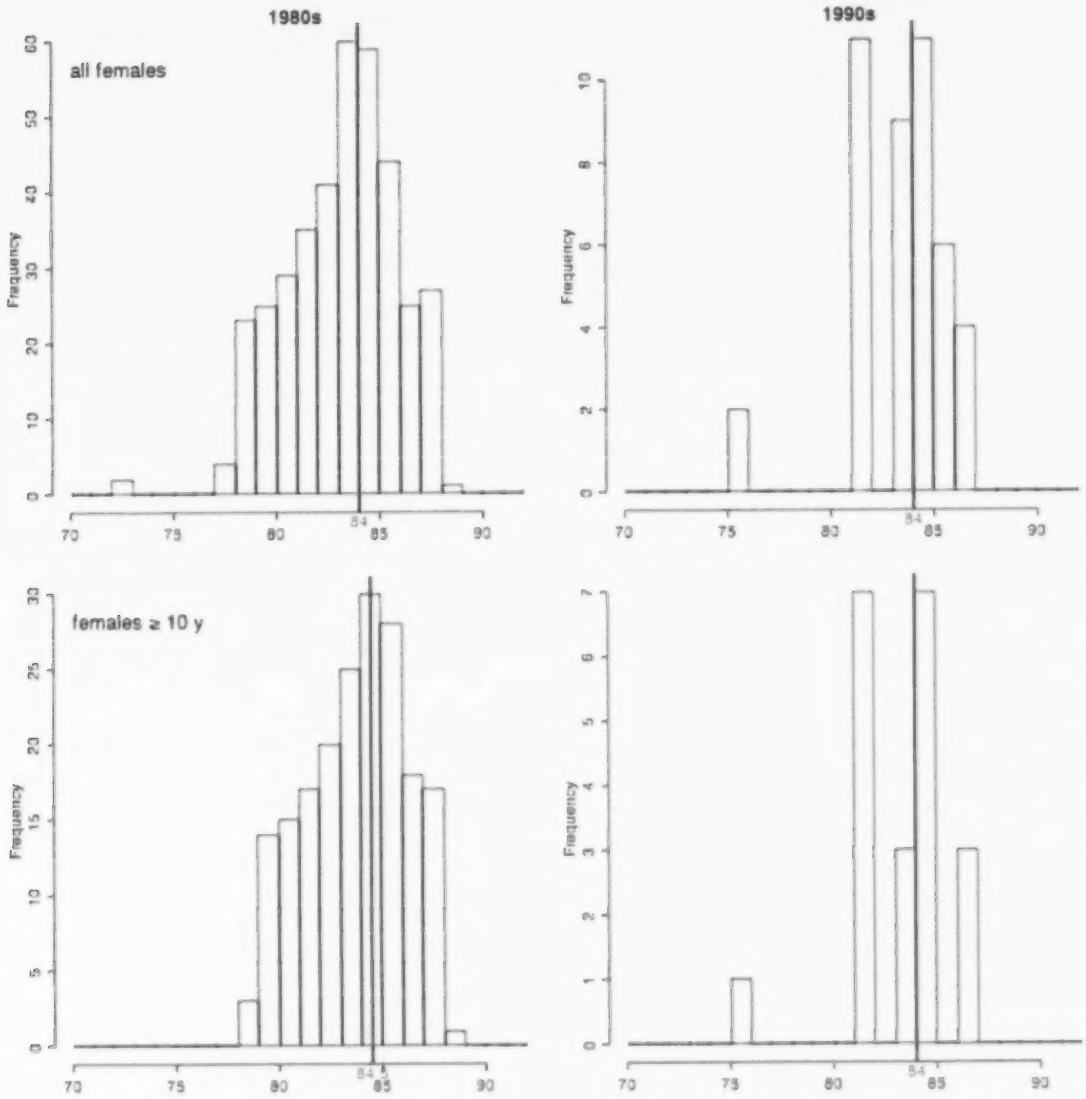


Figure 25. Frequency distribution of sampling dates for female hooded seals during the reproduction period in the 1980s (left) or 1990s (right). Top: All females. Bottom: Only females 10 years and older. The vertical bar extending down to the abscissa shows the median sampling date.

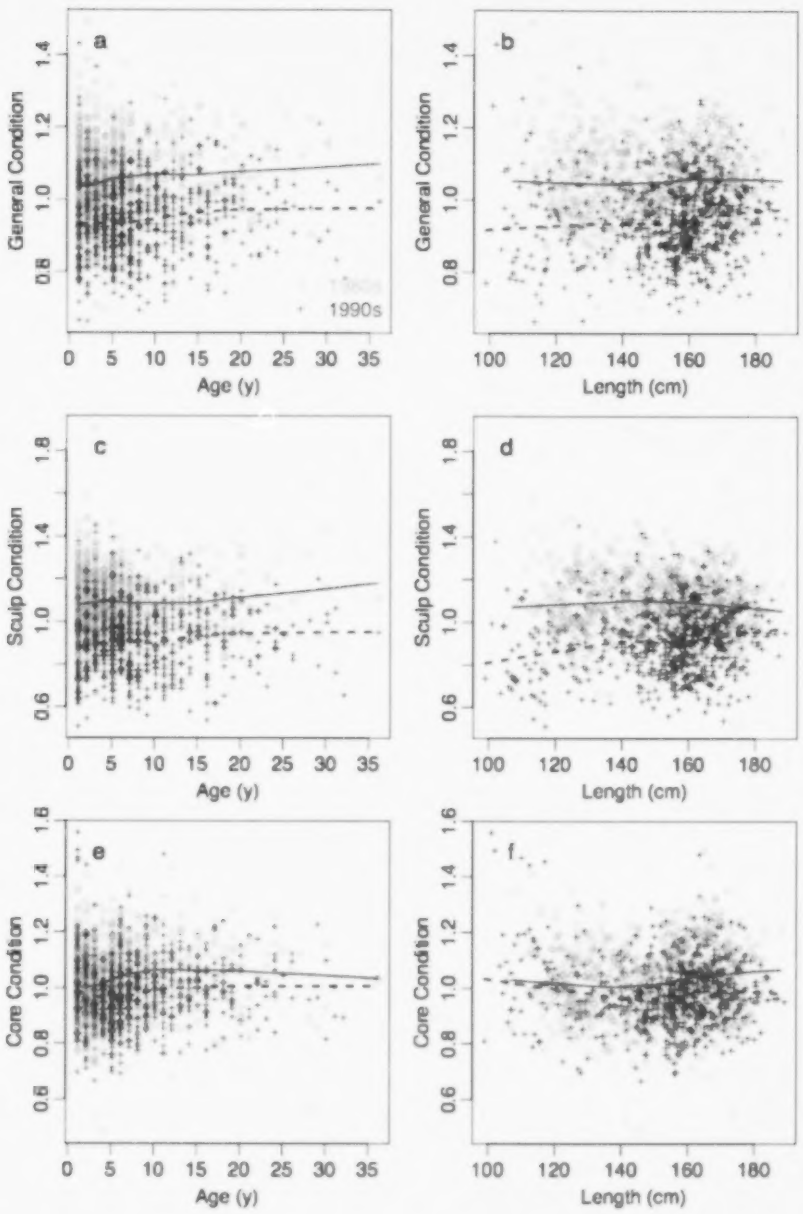


Figure 26. Relationship between general, sculp, and core condition, and either age or length of male harp seals in late-moult period for the 1980s (solid line, blue symbols) and the 1990s (green symbols, dashed line).

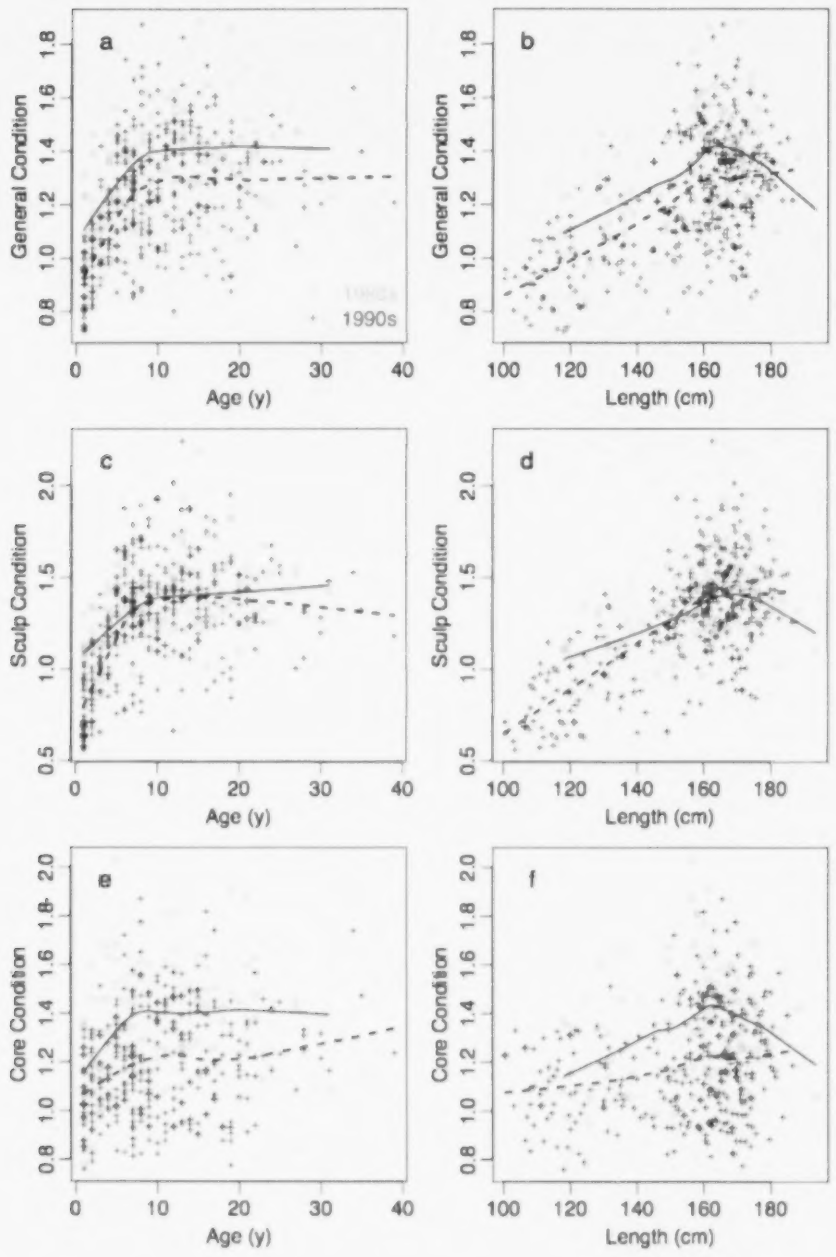


Figure 27. Relationship between general, sculp, and core condition, and either age or length of female harp seals during the pre-reproduction period for the 1980s (solid line) and the 1990s (dashed line).

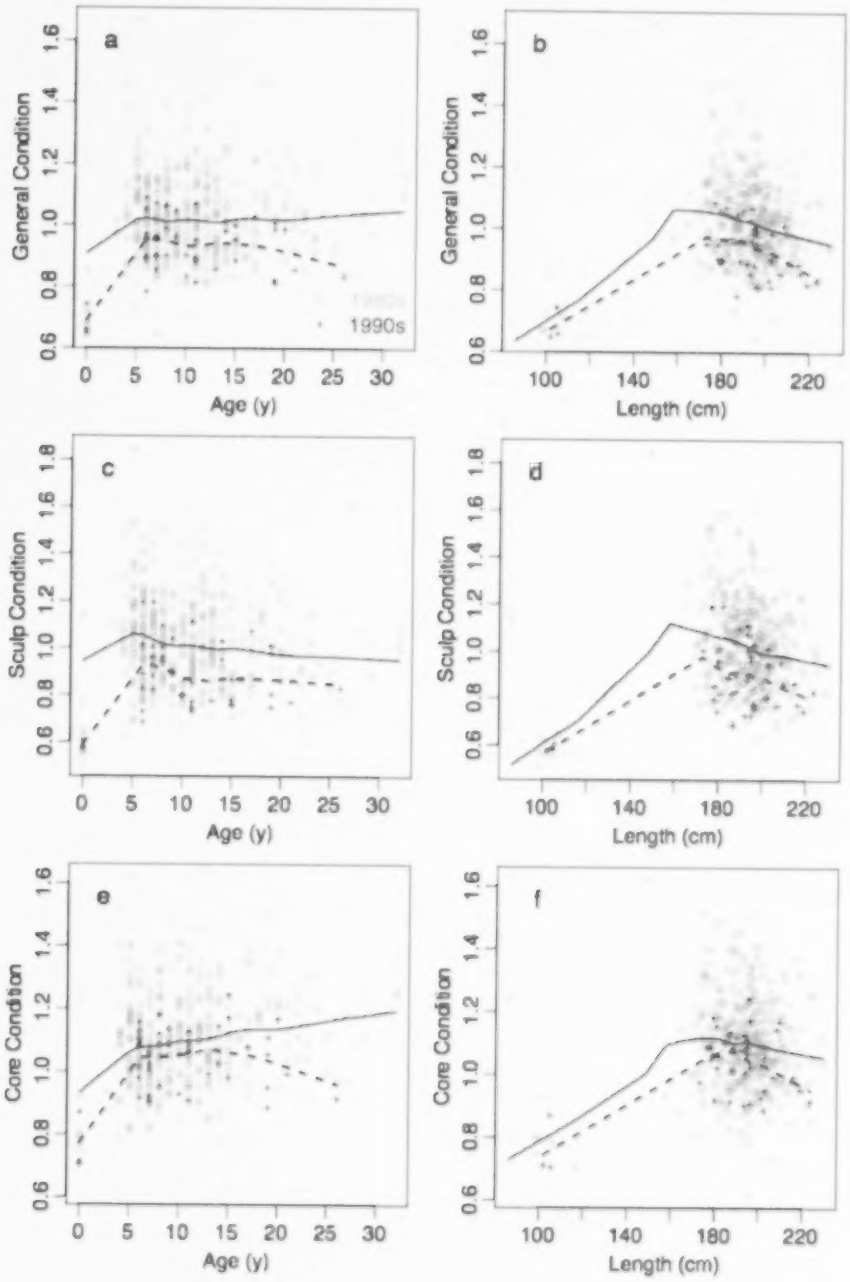


Figure 28. Relationship between general, sculp, and core condition, and either age or length of female hooded seals during the reproduction period for the 1980s (solid line) and the 1990s (dashed line).

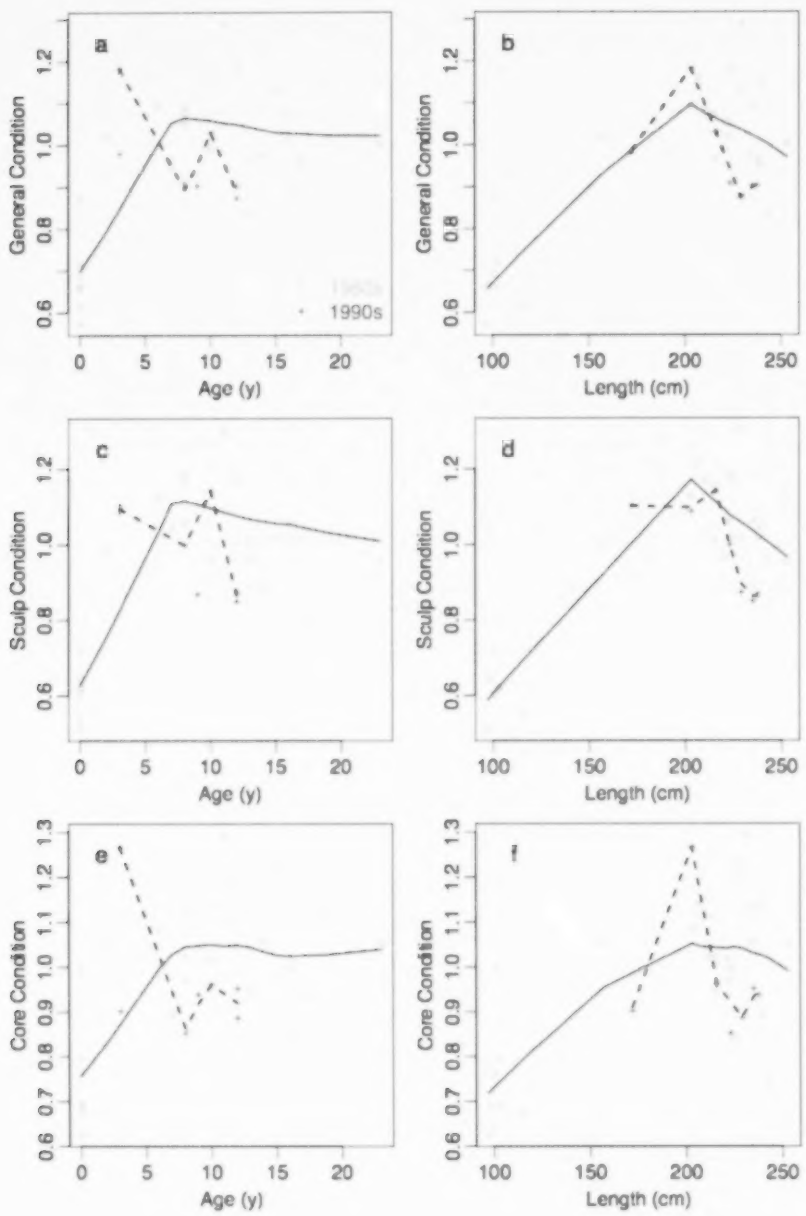


Figure 29. Relationship between general, sculp, and core condition, and either age or length of male hooded seals during the reproduction period for the 1980s (solid line) and the 1990s (dashed line).

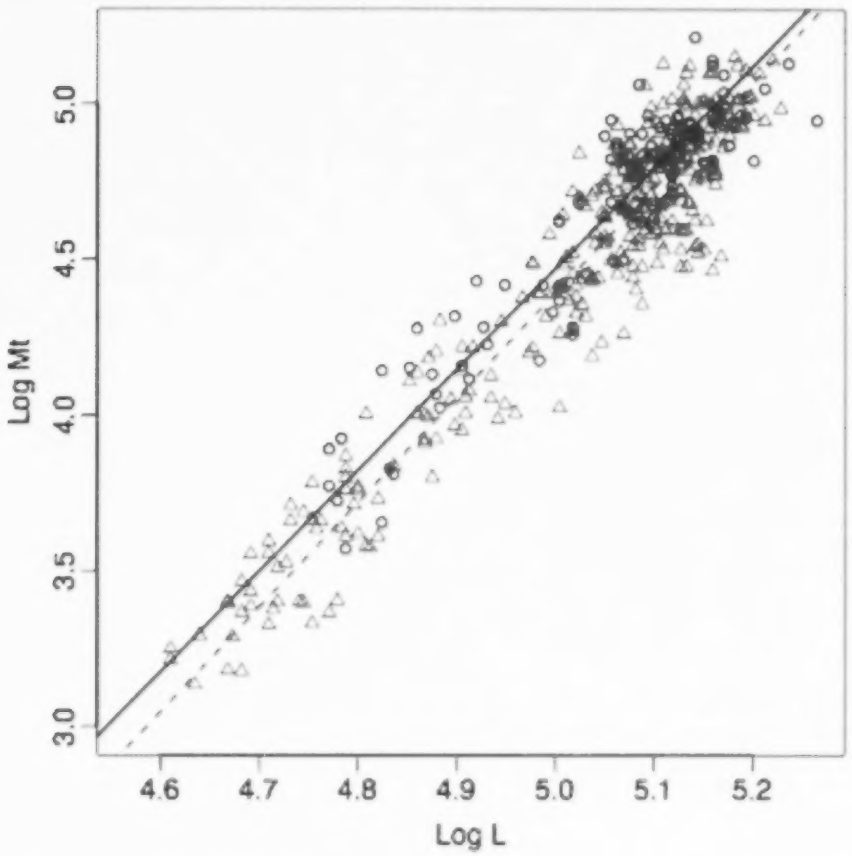


Figure 30. Type II regression lines of total body mass on length (both log-transformed) for female harp seals during the reproduction period. Blue circles and solid line: 1980s. Red triangles and dashed line: 1990s. Slopes did not differ significantly between the 1980s and 1990s, but the intercept was significantly less during the 1990s than 1980s.

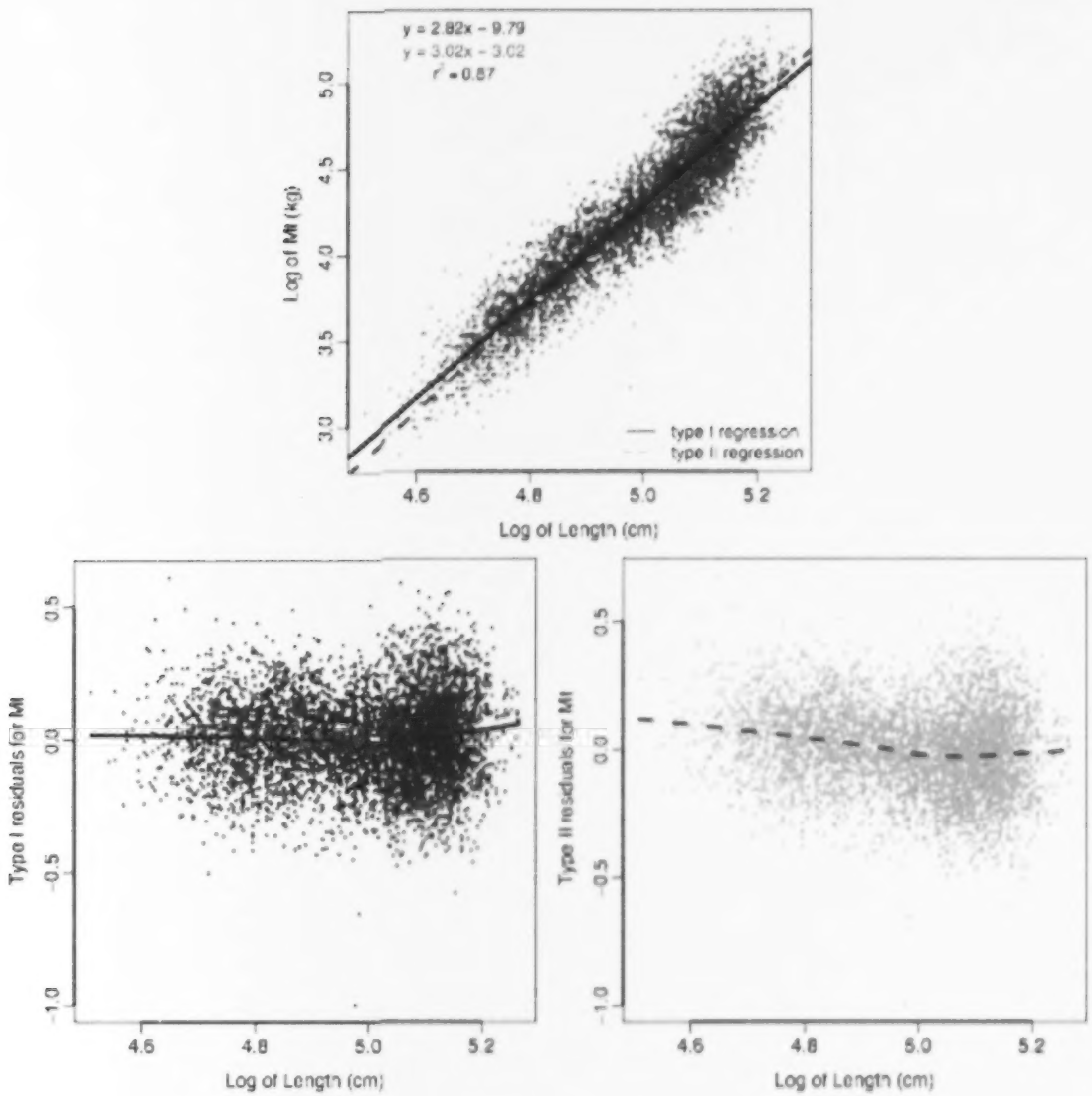

y = 2.82x - 9.79
y = 3.02x - 3.02
r² = 0.87
type I regression
type II regression
Log of Mt (kg)
Log of Length (cm)
Type I residuals for Mt
Type II residuals for Mt
Log of Length (cm)
Log of Length (cm)

Figure 31. Relationship between total mass (Mt) and length (both log-transformed) for male harp seals. Upper panel: Type I and II regressions. Bottom left: Residuals from Type I regression plotted against length. Bottom right: Residuals from Type II regression plotted against length.

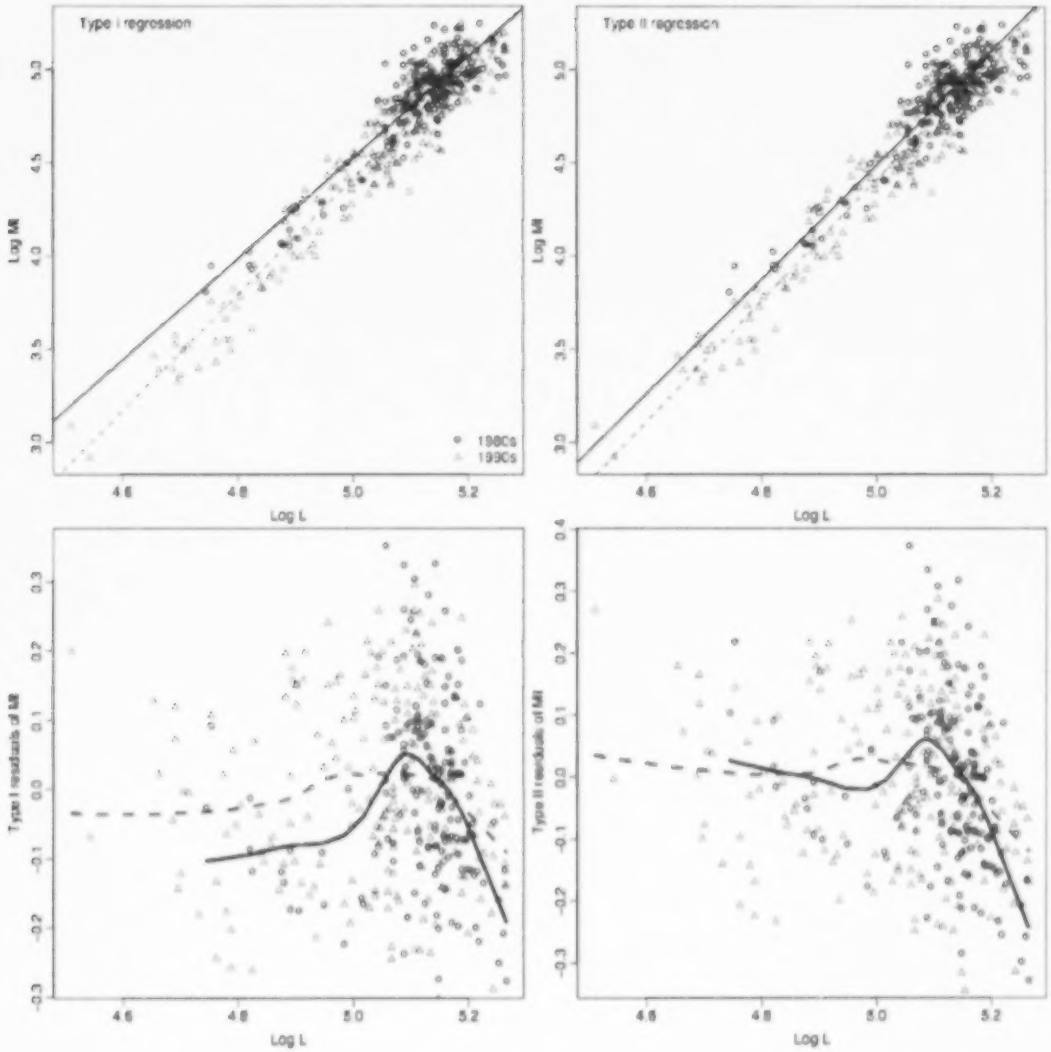


Figure 32. Regression of mass (Mt)-at-age for male harp seals during the pre-reproduction period for the 1980s and 1990s. Left: Type I regression. Right: Type II regression.

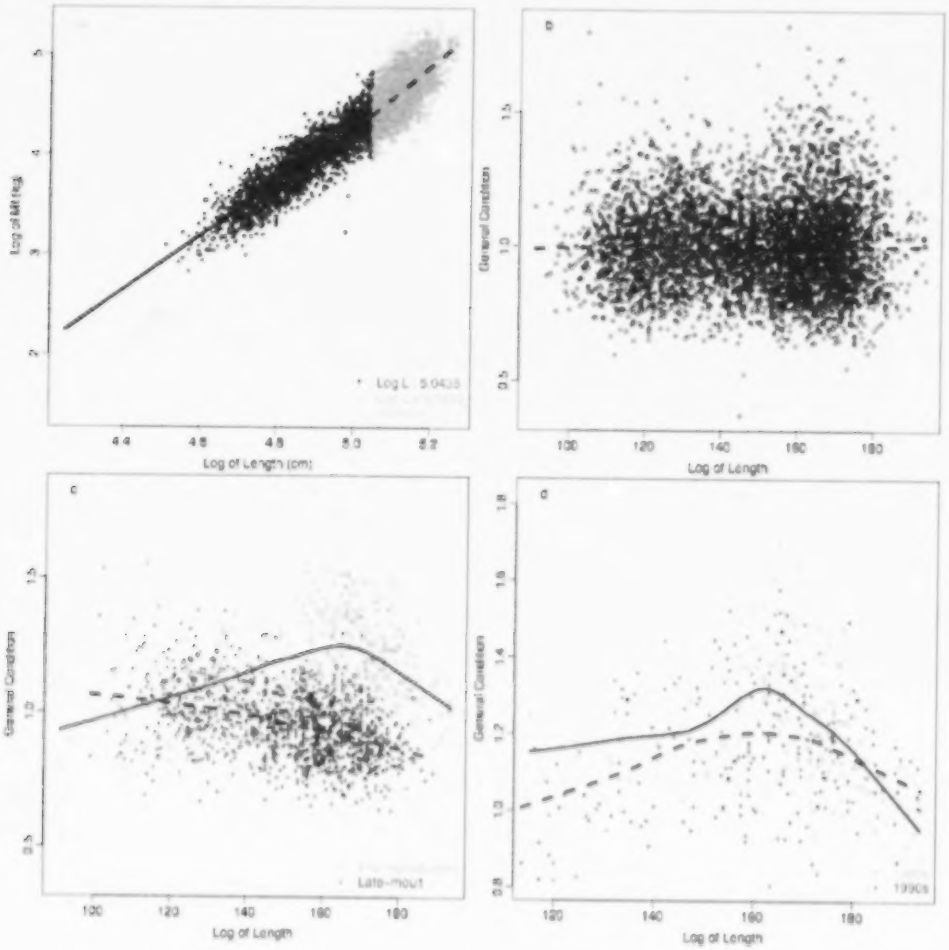


Figure 33. Segmented regression fitted to Mt and length (both log transformed) of male harp seals (a). All data except newborn seals were combined to compute this relationship. (b) General condition index computed from the relationship in (a) as a function of length of male harp seals. Newborn seals are not shown. The index was not related to length. (c) General condition index for seals sampled during the pre-reproduction and the late-moult periods, hiding seals sampled during other periods. (d) General condition of male harp seals sampled during the pre-reproduction period of the 1980s and of the 1990s. In (c) and (d), residuals were related to length within group.

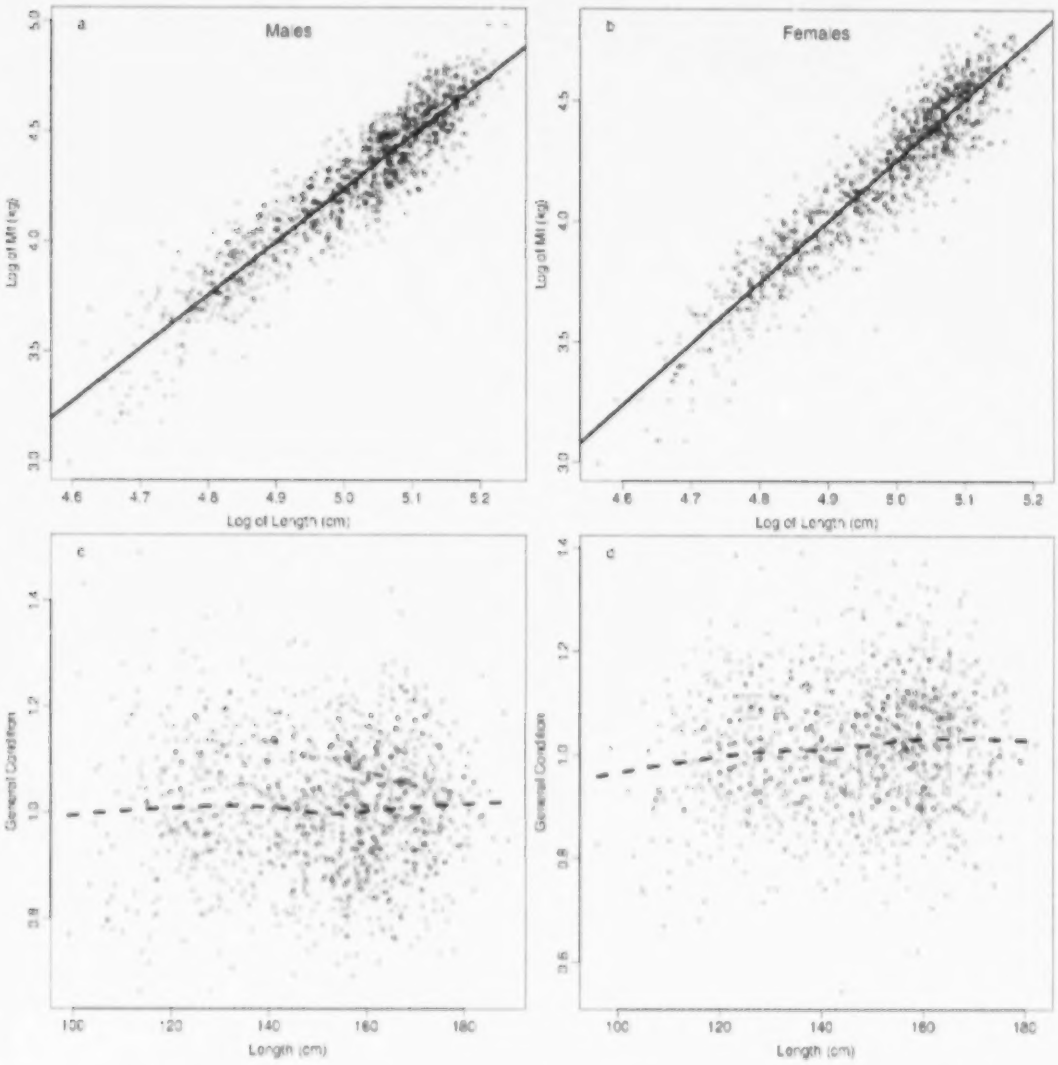


Figure 34. Linear relationship (Type 1 regression) between Mt and L (both log-transformed) of male (a) and female (b) harp seals during the late-moult period; general condition as a function of length for males (c) and females (d).

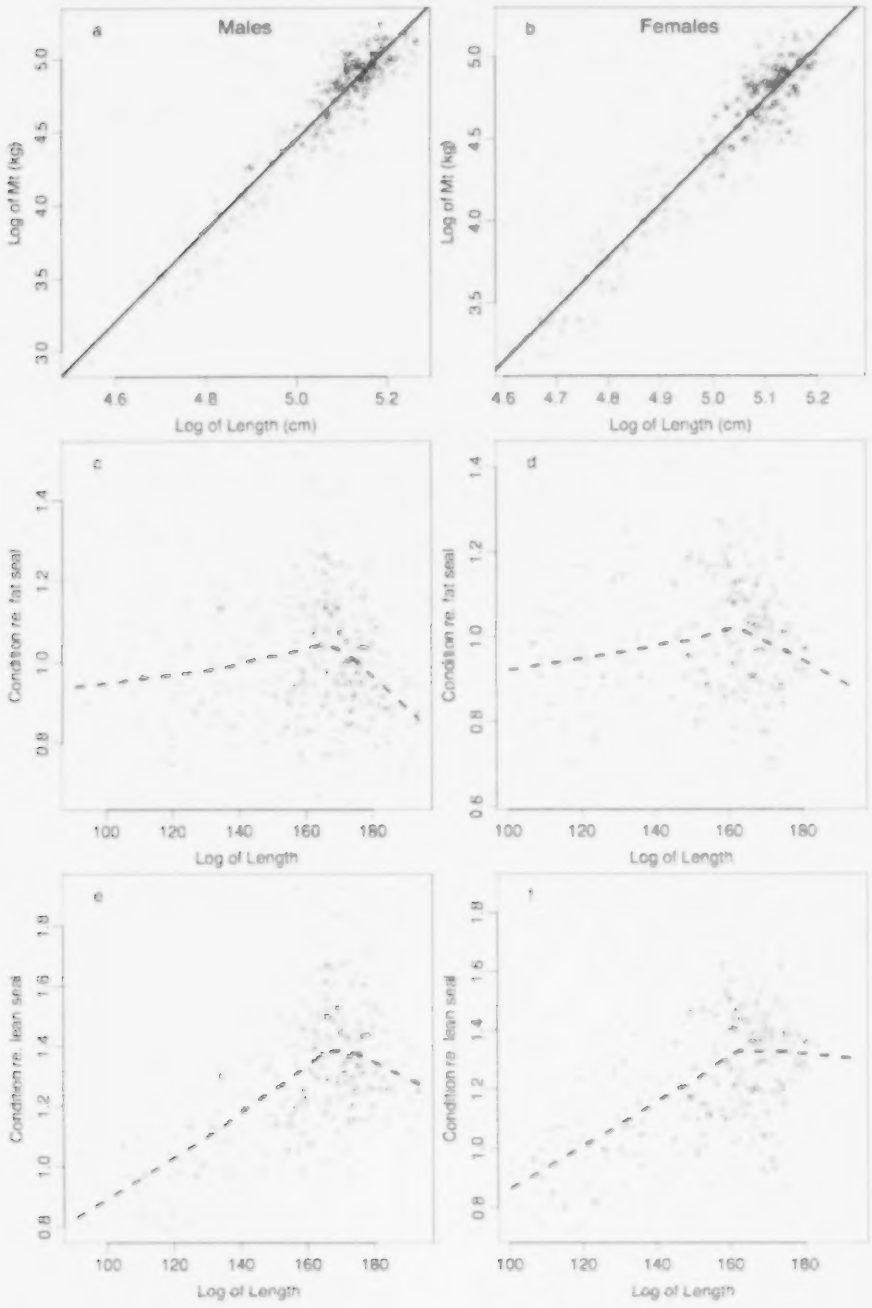


Figure 35. Linear relationship between Mt and L of male (a) and female (b) harp seals during the pre-reproduction period; general condition, calculated relative to mass-at-length of seals sampled during the pre-reproduction period (c and d) and relative to mass-at-length of seals sampled during the late-moult period (e and f).

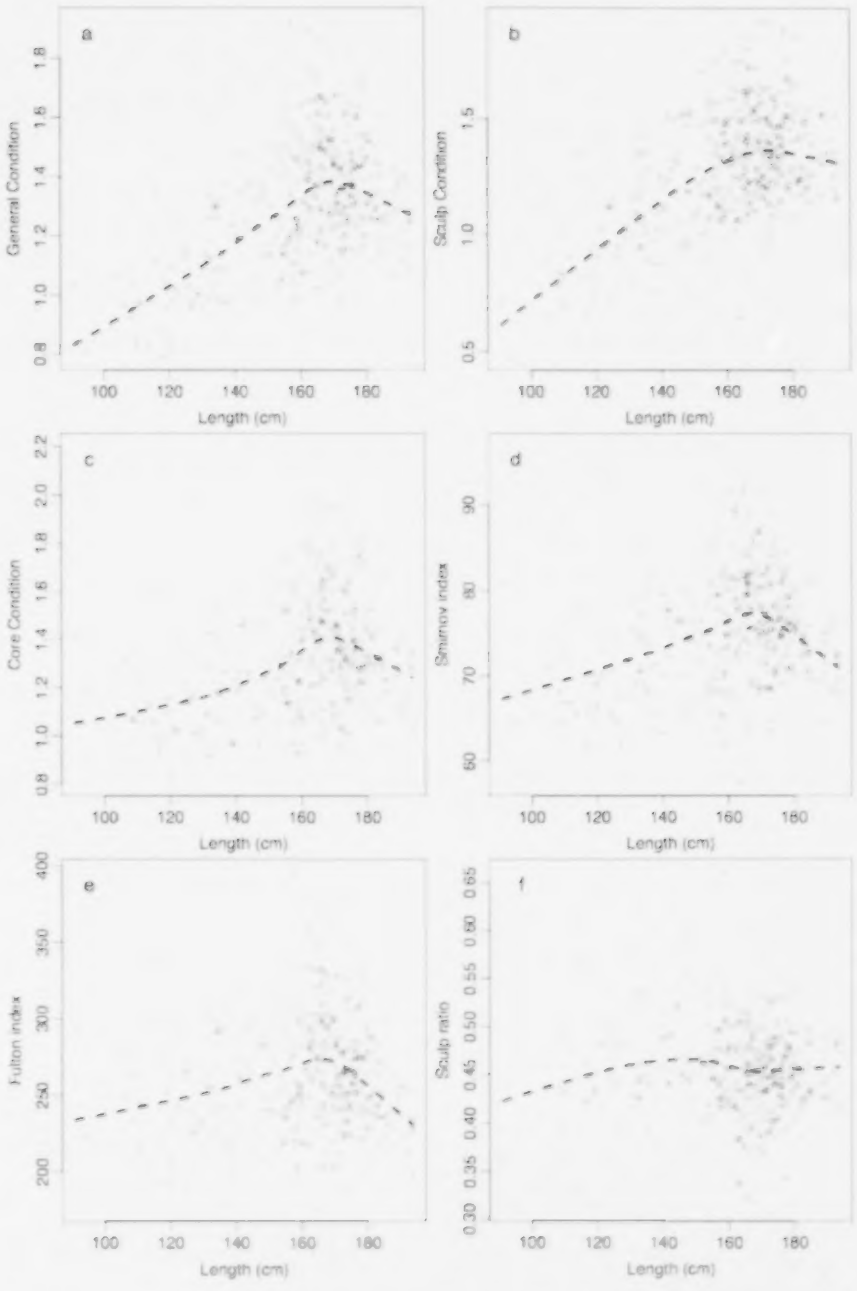


Figure 36. Effect of length on six condition indices for male harp seals sampled in pre-reproduction. General, sculp, and core condition indices were calculated by using allometric relationships based on seals sampled in late-moult period. All indices are affected by body length.

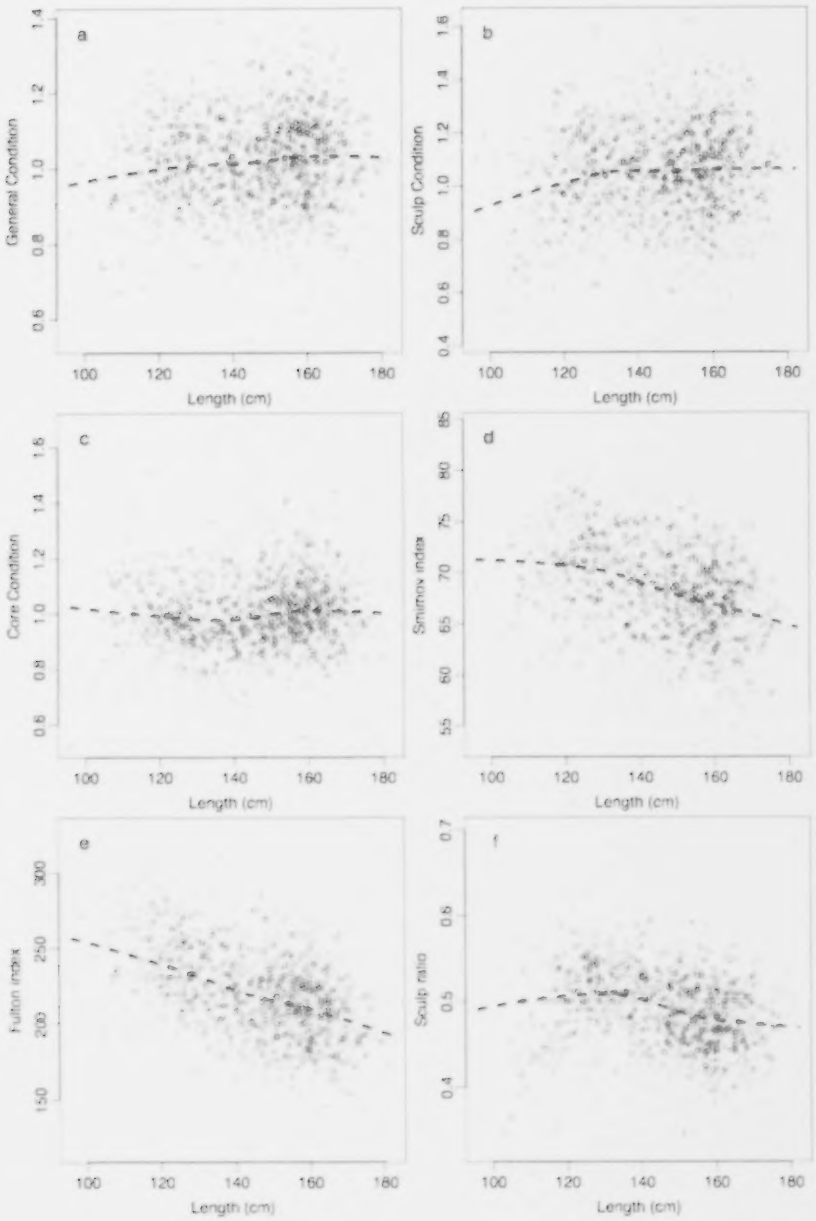


Figure 37. Effect of length on six condition indices for female harp seals sampled in the late-moult period. General, sculp, and core condition indices were calculated using allometric relationships based on seals sampled during that same period. All indices were affected by body length.

4.8 Comparative Analyses of Groundfish Condition in Divs. 4VW and 4X from 1970 to 2006

N.L. Shackell presented a paper on this topic (with K.T. Frank as co-author).

The authors compared biomass and condition trends of 4 trophic groups (piscivores, large benthivores, medium-sized benthivores, pelagic predators) between the eastern (Div. 4VW) and western (Div. 4X) Scotian Shelf (Table 6). The trends in aggregate biomass showed that 3 of 4 groups were declining in east, but there had been compensation in the west (Fig. 38), possibly due to warmer temperatures, which result in increased demographic rates. There was a compensatory response of some species in the east (e.g. red hake, winter flounder), but not quickly enough to show compensation yet. The authors' index of condition was predicted weight at the average long-term length (from 1970-2006) for each species. To display group trends, the standardized condition anomalies were weighted by species biomass and aggregated. In general, aggregated condition was lower in the later period in all groups in both areas, although the trend is less clear for medium-sized benthivores (Fig. 39). Spatially, using data provided by J. Choi (DFO), the condition of all fish was much higher early in the time series than it is now. There has been a general diminution and fragmentation across the Shelf (Fig. 40). Declines in condition can occur if resources become limiting as population size increases, or the optimum temperature for efficient metabolic rate is limiting, or fishing causes changes in prey availability, bottom habitat, or size-selective mortality. In a given cohort, capacity for greater growth potential (larger size) is related to higher condition, in that healthier, well-fed fish within a cohort reach larger sizes. If growth rate and condition are related, then the authors may be seeing indirect consequences of size-selective fishing mortality. Size-selective mortality, specifically the preferential culling of large fish, can change life-history traits, which has been shown in a wide variety of species and locales (e.g. Conover and Munch 2002; Fleming et al. 2002; Reznick and Ghalambor 2005; Yoneda and Wright 2005; Conover et al. 2005). Locally, size-selective mortality (on larger fish) has been inferred to occur in Newfoundland and Gulf of St. Lawrence cod (Olsen et al. 2004; Swain et al. 2007) but has not been examined here. In a preliminary examination of the causes of trends in condition, the authors modelled condition as a function of landings (fishing), temperature (effects on metabolic rate), population biomass (density dependence), and length-at-age (growth) for cod, haddock, pollock, and silver hake in both the east and west. The authors did not include an index of prey availability nor an index of the change in bottom habitat, as the authors reasoned that there were lots of pelagic prey available and that changes in bottom habitat would not be a generalized cause of decline in condition given that the authors observed a decline in some species of pelagic predators. The authors used a stepwise regression to select independent variables for use in a generalized additive model (GAM) with smooth regression. Degrees of freedom were fixed according to GAM protocol. The amount of variation explained was generally low to moderate across species (Table 7), which may reflect the authors' crude choice of indices rather than being conclusive about the effects of fishing, temperature, and population biomass. Notably, growth was significant in 5 of 8 populations (e.g. Fig. 41). Declines in growth rates are related to declines in condition. Lower condition can result in higher mortality and slower growth (affects ability to escape predators and catch prey), as well as increased incidence of disease. Low productivity stocks (those in extreme environments) show greater extremes in growth and condition because peak growth occurs in shorter period. Given the importance of condition to productivity, it would be worthwhile pursuing the relationship between individual growth rates, condition, and size-selective mortality.

Table 6. Species within trophic groups based on maximum body size (http://www.fishbase.org/search.php) and diet. Diet information from Link and Almeida (2000) and Bundy (2005). The last column shows species for which there is condition information on the VDC.

Group/Species	Scientific name	Condition Info
Piscivores		
Cod	*Gadus morhua*	C
Halibut	*Hippoglossus hippoglossus*	C
Pollock	*Pollachius virens*	C
White hake	*Urophycis tenuis*	C
Monkfish	*Lophius americanus*	C
Spiny dogfish	*Squalus acanthias*	C
Cusk	*Brosme brosme*	C
Turbot	*Reinhardtius hippoglossoides*	
Large Benthivores		
American plaice	*Hippoglossoides platessoides*	C
Haddock	*Melanogrammus aeglefinus*	C
Wolffish	*Anarhichas lupus*	C
Winter skate	*Leucoraja ocellata*	C
Thorny skate	*Amblyraja radiata*	C
Ocean pout	*Macrozoarces americanus*	C
Barndoor skate	*Dipturus laevis*	
Hagfish	*Myxine glutinosa*	
Medium Benthivores		
Winter flounder	*Pseudopleuronectes americai*	C
Witch flounder	*Glyptocephalus cynoglossus*	C
Yellowtail flounder	*Limanda ferruginea*	C
Little skate	*Leucoraja erinacea*	
Smooth skate	*Malacoraja senta*	C
Windowpane flounder	*Scophthalmus aquosus*	
Black dogfish	*Centroscyllium fabricii*	
longhorn sculpin	*Myoxocephalus octodec*	C
Pelagic Predators		
Silver hake	*Merluccius bilinearis*	C
Redfish	*Sebastes sp.*	C
Sea raven	*Hemitripterus americanus*	C
Red hake	*Urophycis chuss*	C
Long-fin hake	*Urophycis chesteri*	
Offshore hake	*Merluccius albidus*	
Fourspot flounder	*Hippoglossina oblonga*	

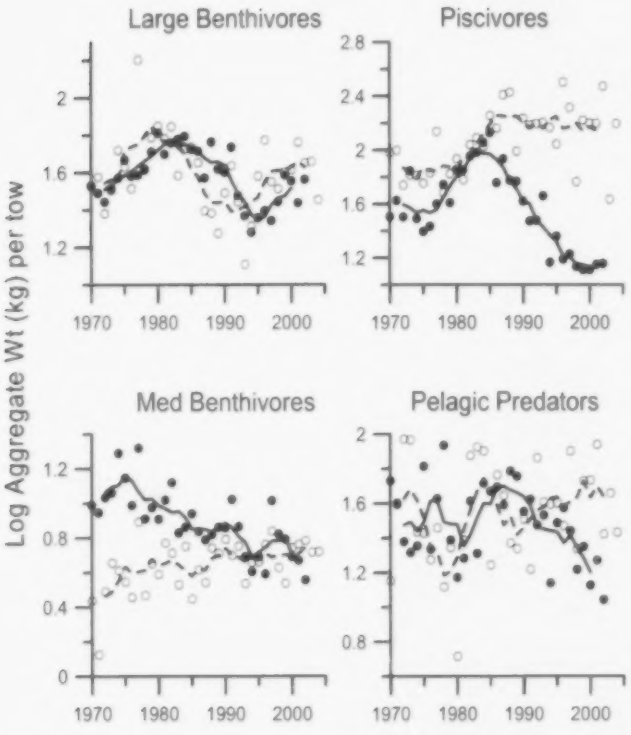


Figure 38. Aggregated biomass for each trophic group.

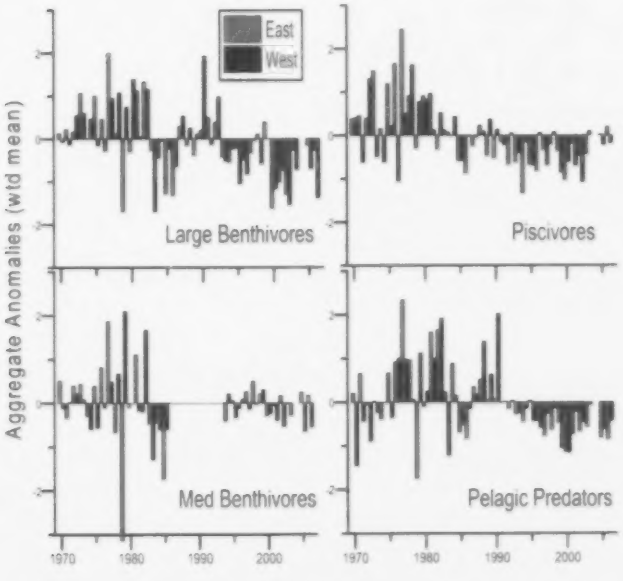


Figure 39. Standardized anomalies of condition weighted by species biomass for each trophic group.

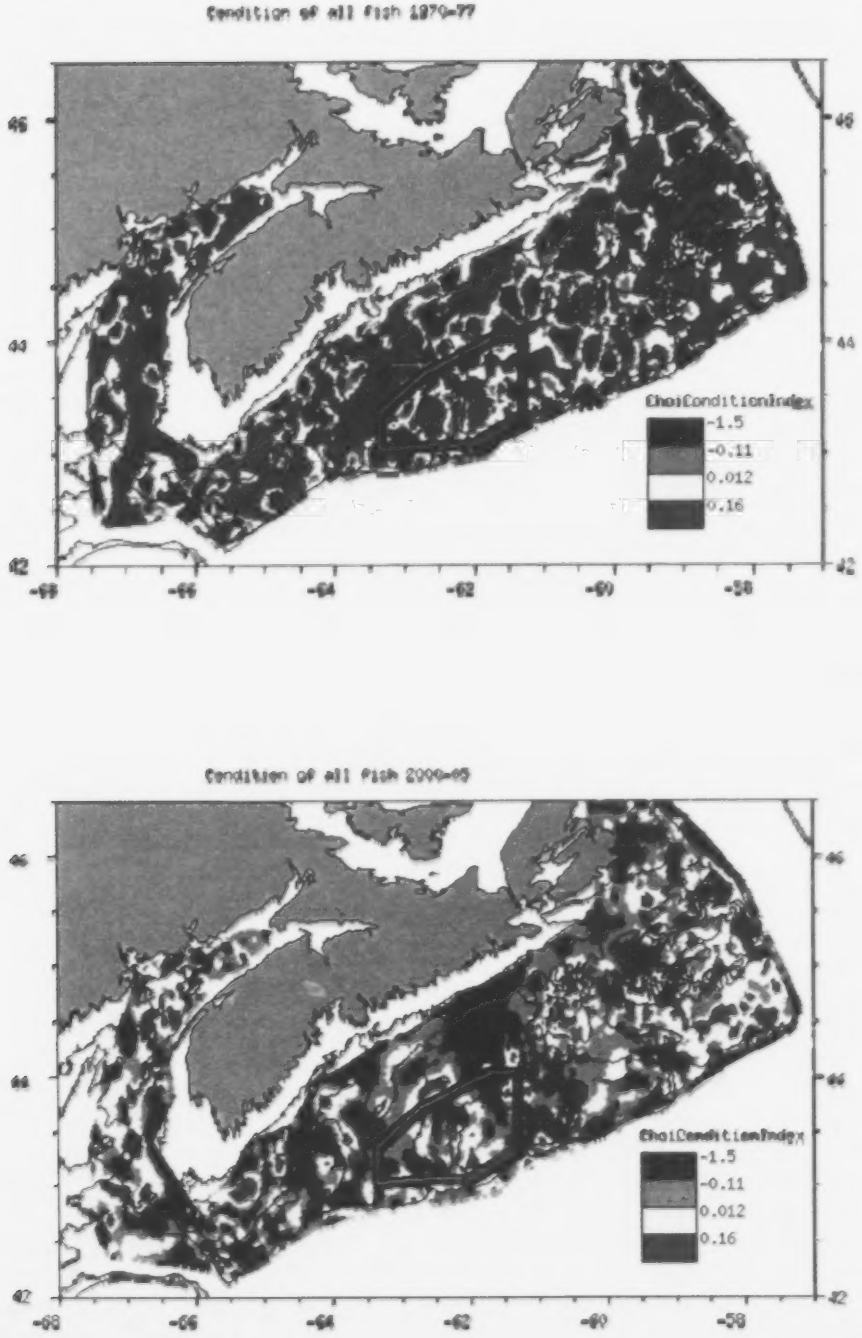


Figure 40. Spatial pattern of condition (all fish) in early (1970-1977) and late (2000-1905) periods.

Table 7. GAM summary results for four species in two regions.

Species	Region	AdjR2	Lands	TempC	PopBM	Growth
cod	E	0.54				
	W	0.12				
haddock	E	0.3				
	W	0.11				
pollock	E	0.47				
	W	0.38				0.01
silverhake	E	0.13				
	W	0.08				

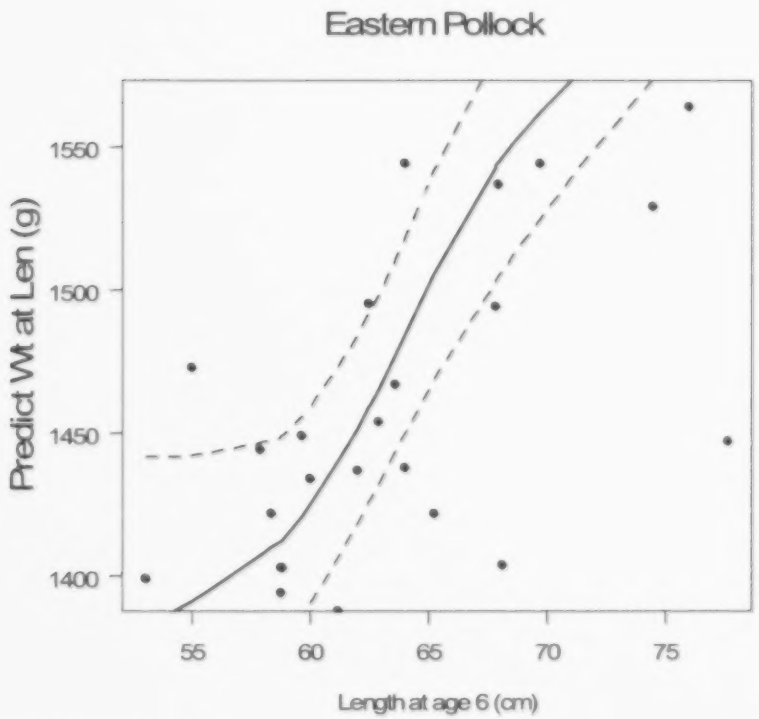


Figure 41. Example of significant effect of growth rate on condition. Blue line is smoothed fitted values, dashed red lines represent the 95% CI and the points are observations.

Table 7. GAM summary results for four species in two regions.

Species	Region	AdjR2 Lands	TempC	PopBM	Growth
cod	E	0.54		<0.05	<0.001
	W	0.12	<0.05		
haddock	E	0.3			<0.001
	W	0.11	<0.05		
pollock	E	0.47			<0.001
	W	0.38	<0.05		<0.01
silverhake	E	0.13			<0.05
	W	0.08			

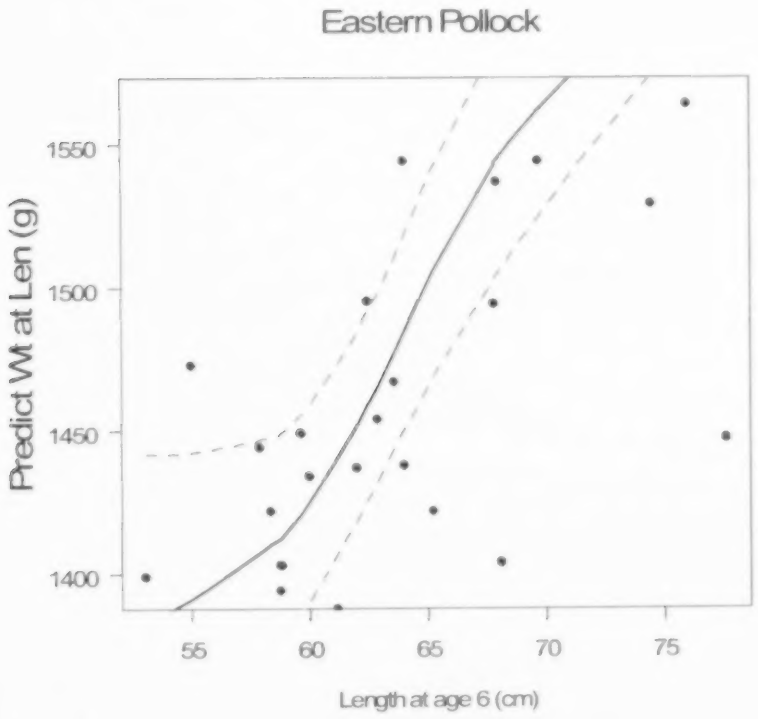


Figure 41. Example of significant effect of growth rate on condition. Blue line is smoothed fitted values, dashed red lines represent the 95% CI and the points are observations.

4.9 Condition Estimates and Scotian Shelf Haddock

A.B. Neuheimer presented a paper on this topic (with C.T. Taggart as co-author).

Many factors affect variation in size-at-age in fishes, including temperature, food consumption, and size-selective fishing. The effects of these factors on the variation in size-at-age must be disentangled to allow for successful management strategies to be developed. In this study, the authors examine the various factors affecting size-at-age in Scotian Shelf (divs. 4VW) haddock (*Melanogrammus aeglefinus*), where a drastic decline in size-at-ages 3+ was observed over the past 30 years coincident with high fishing pressure and changing environmental conditions (Fig. 42) (Frank et al 2001).

Temperature has been identified as a controlling factor on fish size-at-age. Others have argued that variation in size-at-age due to variation in temperature should be explained before other factors are explored (Brander 1995). The authors argue that the relevant metric for examining the effect of variation in temperature on size-at-age in most fishes is the thermal integral parameterized in the growing degree-day (GDD, °C•d) metric (Neuheimer and Taggart 2007). The authors employ the GDD metric to examine the changes in size-at-age of Div. 4VW haddock from 1969 through 2003 in relation to variation in physiologically relevant temperature (GDD; Fig. 43). Significant variation in Length-at-Day (LaD) among year-classes (decline in slopes and intercepts of LaD-at-GDD relations) remains after LaD variation due to GDD (temperature) is explained (Fig. 44). The authors present evidence that the remaining temperature-independent length-at-age variation among stocks is consistent with the sustained size-selective fishing of large fish (fast-growing, late-maturing) of this stock (Fig. 45). The authors argue size-selective fishing is the most parsimonious explanation for the systematic declines in size-at-age and age-at-maturity (Fig. 46) found in 4VW haddock.

The authors' findings have implications regarding the interpretation of variation in relative condition (Kn; the most appropriate of condition formulations) for this stock. When the authors use a single parameterization of relative condition over the entire time series, the authors find a significant discontinuity (~1982) in the condition estimates from a period of "good" condition to a period of "poor" condition (Fig. 47). However, when the authors account for that variation in condition that is likely resulting from changes in the population mean growth dynamics most parsimoniously explained by fishing, the authors find no remaining temporal trend in the variation in relative condition for this stock (Fig. 48). Therefore, changes in condition that may be interpreted as changes in food availability or quality may in fact be only an artifact (i.e. a product of human conception rather than an inherent element) of the changes in growth dynamics explained by fishing selection.

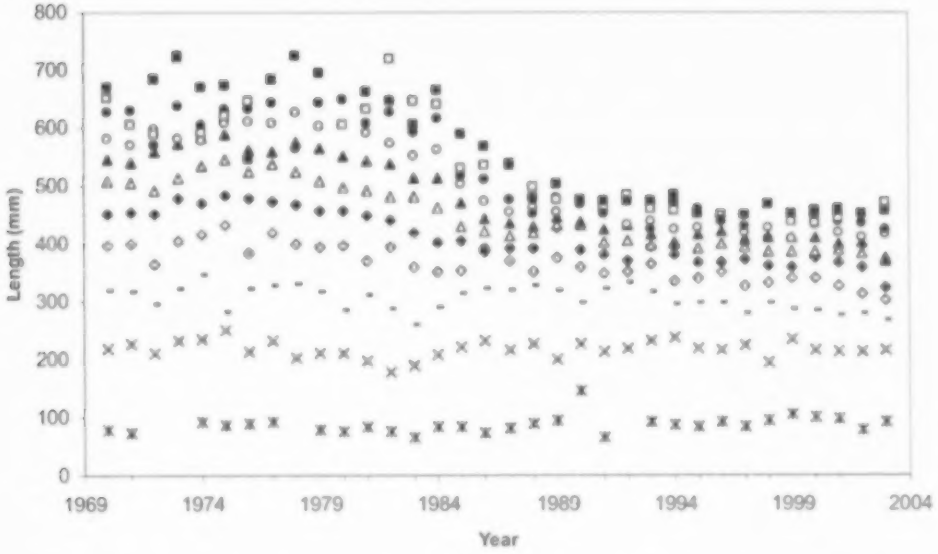


Figure 42. Variation in length-at-age (mm) for Div. 4VW haddock from 1970 to 2003 (Frank et al. 2001). Symbols indicate age-0 (star), -1 (cross), -2 (horizontal line), -3 (open diamond), -4 (filled diamond), -5 (open triangle), -6 (filled triangle), -7 (open circle), -8 (filled circle), -9 (open square), -10 (filled square).

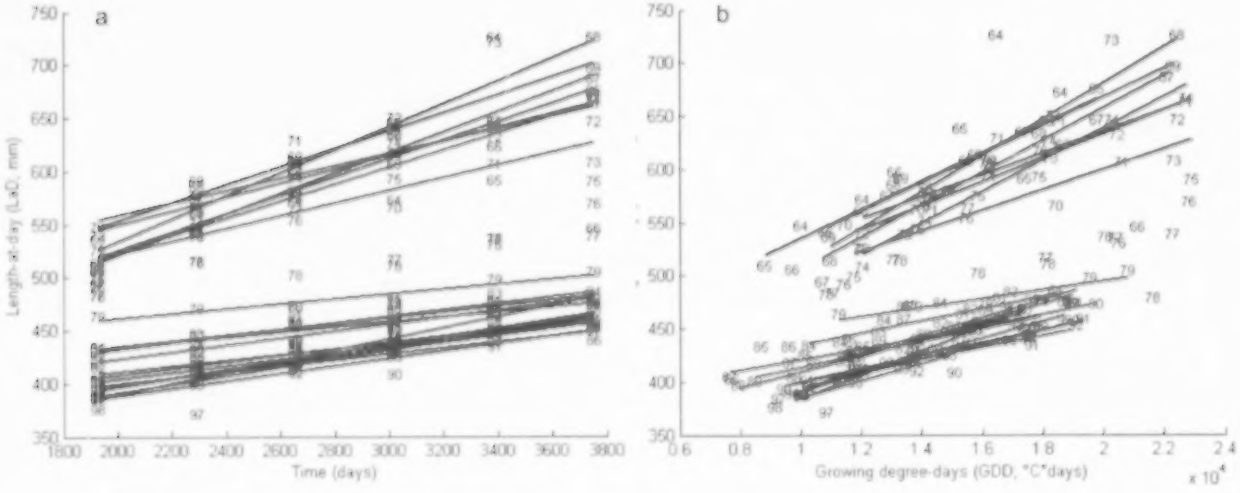


Figure 43. Length-at-day (mm) for Div. 4VW haddock ages-5 to -10 as a function of: a) calendar time (days, no significant relation among year-classes, ANCOVA, different slopes P<0.0001); and (b) GDD (°C•days, no significant relation among year-classes, ANCOVA, different slopes P<0.0001). Data-labels denote year-class decade and year in the 1900s. Reproduced from Neuheimer et al. submitted.

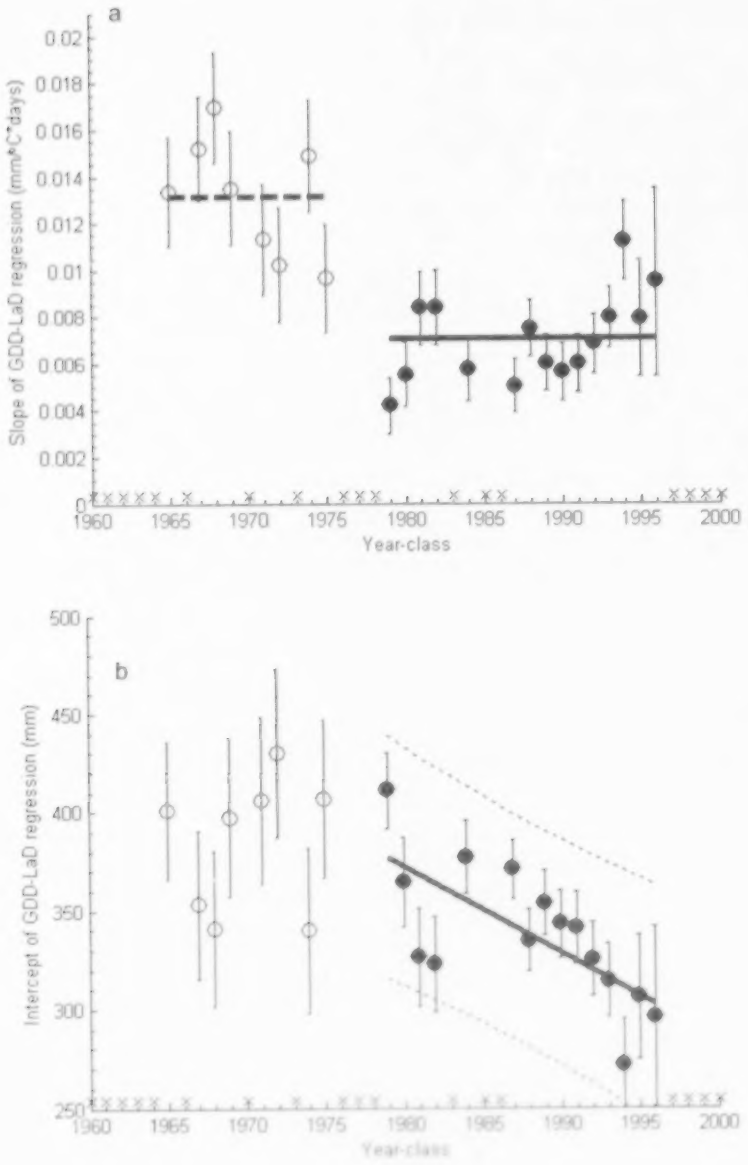


Figure 44. Parameters of the LaD-at-GDD relation for early (<1979, open circles) and late (≥1979, filled circles) year-classes. (a) Slopes, mm•(°C•days)$^{-1}$, and associated standard error of the LaD-at-GDD relations are statistically similar within early (open circles, dashed horizontal line, ANCOVA, similar slopes P=0.43) and late (filled circles, solid horizontal line, ANCOVA, similar slopes P=0.17) year-classes. Slopes of the LaD-at-GDD relations are statistically higher in early, 0.013 ± 0.0009 mm•(°C•days)$^{-1}$, year-classes than late 0.007 ± 0.0004 mm•(°C•days)$^{-1}$, year-classes (Shapiro-Wilk normality test: P>0.62; 2-sample T-test: P<0.0001). (b) Intercepts, mm, and associated standard error of the LaD-at-GDD relations are statistically different within early (ANCOVA, different intercepts P=0.0018) and late (ANCOVA, different intercepts P=0.17) year-classes. There was a significant decline in intercept among late year-classes (solid line, linear regression, Intercept = -4.3•Year-class + 1x10^{3}mm, r^2=0.50, P=0.003, dashed lines indicate 95% confidence intervals around the prediction) but not early year-classes (linear regression, P=0.71). Crosses denote year-classes with non-significant (P>0.05) LaD-at-GDD relations. Reproduced from Neuheimer et al. submitted.

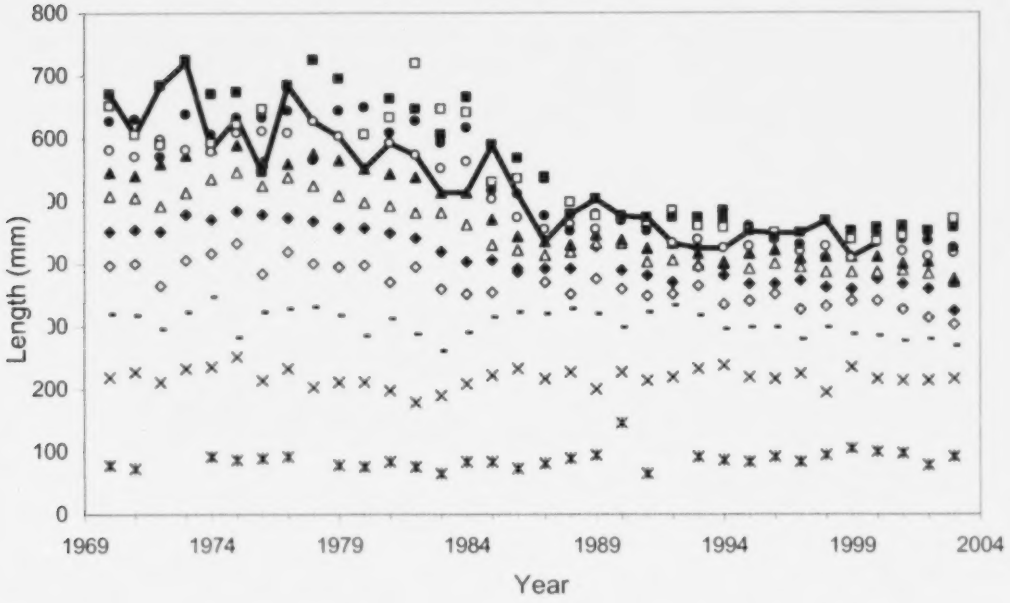


Figure 45. Variation in length-at-maximum-fishing-mortality (mm, solid line) and length-at-age (mm, symbols, Frank et al. 2001) for 4VW haddock from 1970 to 2003. Symbols indicate age-0 (star), -1 (cross), -2 (horizontal line), -3 (open diamond), -4 (filled diamond), -5 (open triangle), -6 (filled triangle), -7 (open circle), -8 (filled circle), -9 (open square), -10 (filled square).

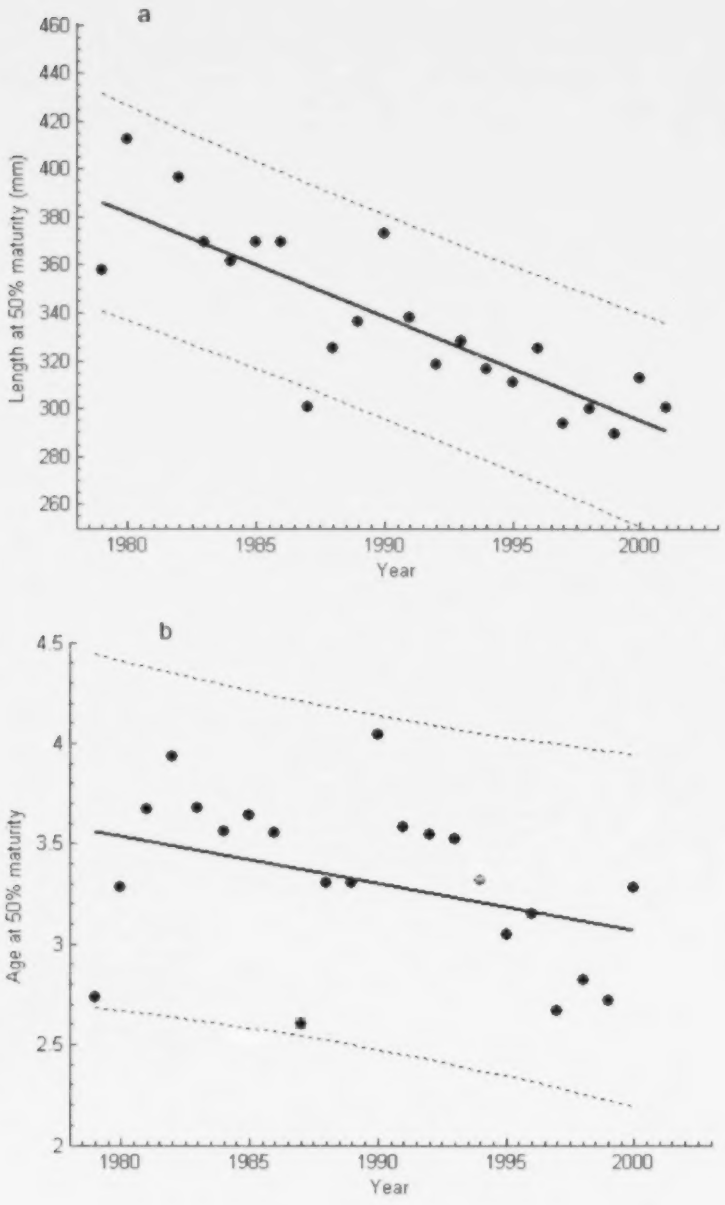


Figure 46. (a) Interpolated length (mm) at 50% maturity for 4VW haddock (source data from Frank et al. 2001). Solid line indicates significant trend (linear regression, length at 50% maturity = -4.3 • Year + 8900 mm, r^2=0.68, P<0.0001), dashed lines indicate 95% confidence intervals around the prediction. (b) Interpolated age at 50% maturity for 4VW haddock (source data from Frank et al. 2001). Solid line indicates marginal trend (linear regression, age at 50% maturity = -0.024 • Year + 50, r^2=0.14, P=0.088), dashed lines indicate 95% confidence intervals around the prediction.

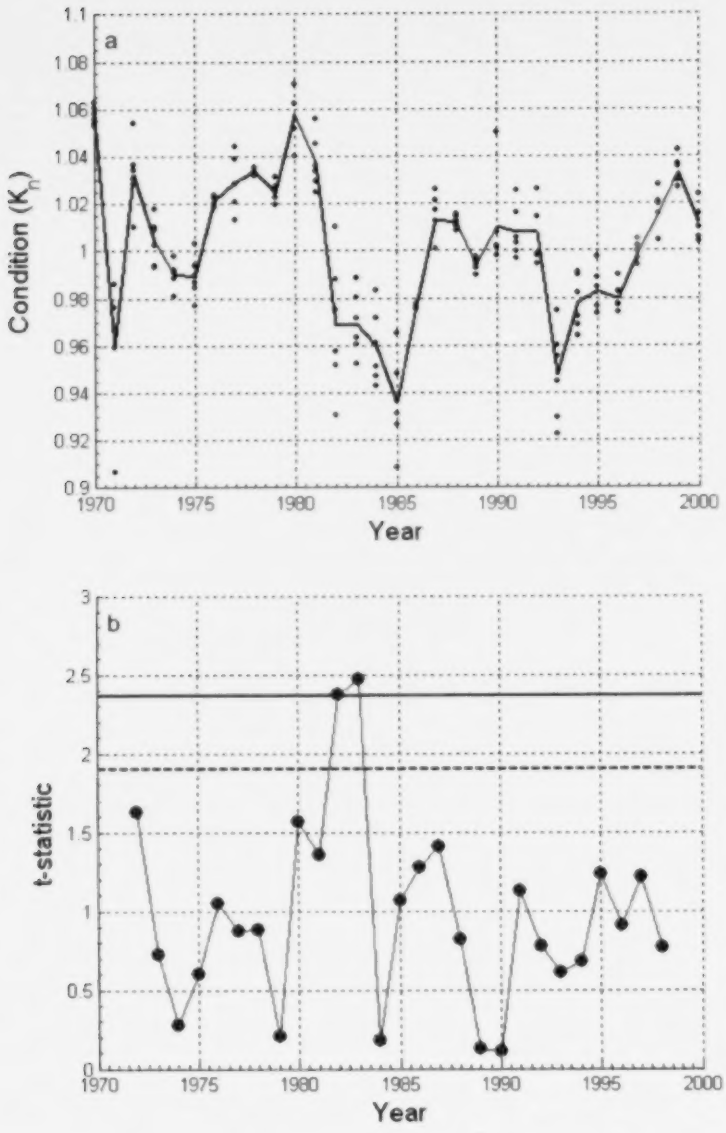


Figure 47. (a) Relative condition (K_n) of 4VW haddock ages-5 through -10 (filled circles) and annual mean K_n (solid line) for 1970 to 2000. (b) Discontinuity analysis for the time series (1970-2000) of mean annual relative condition of haddock. Horizontal lines indicate t-statistic at P=0.10 (broken line) and P=0.05 (solid line). Window=4 years.

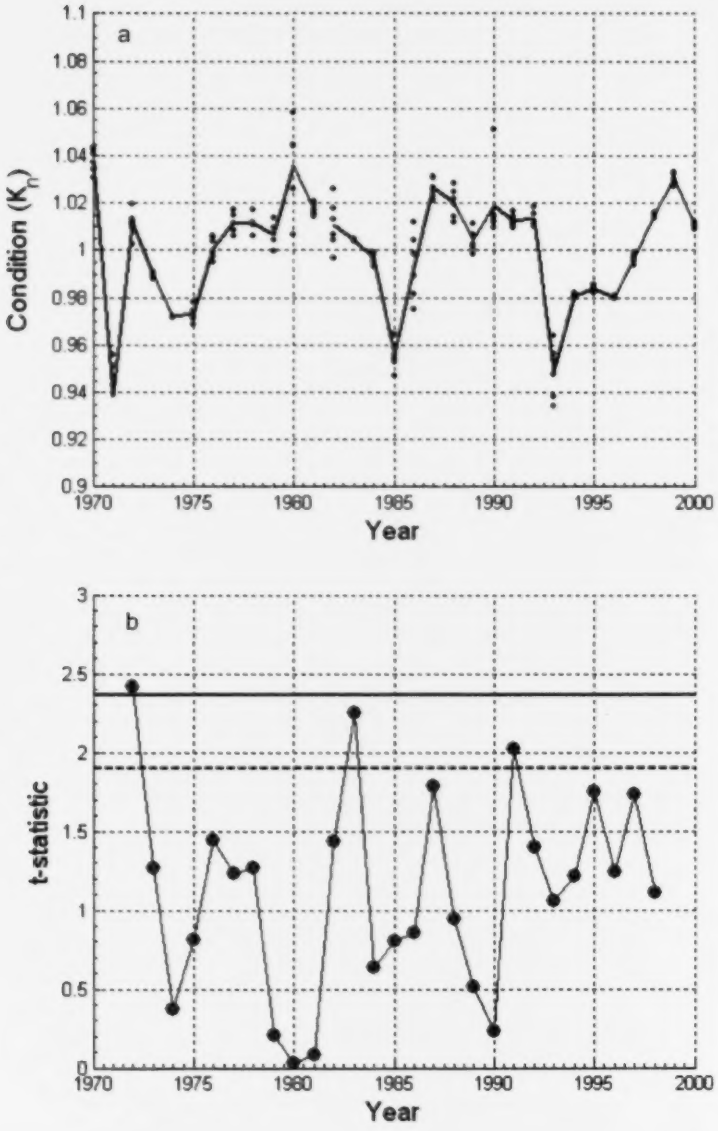


Figure 48. (a) Relative condition (K_n) of 4VW haddock ages-5 through -10 (filled circles) and annual mean K_n (solid line) for 1970 to 2000 evaluated "pre" and "post" the 1981/1982 discontinuity (see Discussion). (b) Discontinuity analysis for the time series (1970-2000) of mean annual relative condition of haddock evaluated "pre" and "post" the 1981/1982 discontinuity. Horizontal lines indicate t-statistic at P=0.10 (broken line) and P=0.05 (solid line). Window=4 years.

4.10 Annual Trends in Meat Weight/Shell Height Relationships for Sea Scallops (*Placopecten magellanicus*)

S. Smith presented a paper on this topic (with co-author S. Rowe).

The adductor muscle or scallop meat is the main product of the scallop fishery and is routinely sampled from fishery catches and stock surveys each year. The size composition of the landings is regulated in terms of average meat weight size in the catch. This muscle is important to the animal for protection (closing the two valves), for propulsion (movement by means of rapid open and closing of valves to eject water), and for energy storage (glycogen stored within muscle).

The weight of the muscle for a given age will change seasonally in response to energy needs for reproduction prior to spawning in August/September, food availability in the spring and fall, and over-wintering when food is lacking. For a given shell height, spatial patterns have been found for adductor muscle weight at a fixed point in time related to depth distribution and food availability (Smith et al. 2001). Smith and Rago (2004) discussed the impact of spatial patterns on providing area-wide fisheries management advice based on yield-per-recruit fishing targets such as F_{max} and $F_{0.1}$.

In addition, there are also annual changes in the weight of the muscle at a given shell height possibly reflecting annual changes in food availability (Ouellet et al. 2001). These changes also have a spatial component possibly indicating annual changes in the spatial distribution of food availability (Fig. 49a, 49b). The authors do not know all of the underlying causes of these spatio-temporal patterns and, hence, cannot predict what they will be in future. Total allowable catches (TAC) in terms of meat weight are set prior to the opening of the fishing season for these fisheries, and the spatio-temporal distribution of adductor weight can result in a higher or lower fishing mortality than expected when the TAC was set.

Starting in 2000, a sampling program was initiated with financial support of the fishing industry in which the same fixed stations off of Digby, Nova Scotia, were sampled for meat weight and shell height on a bi-monthly basis. Weight measurements of gonads and viscera were added in 2003. The sampling was completed in 2004, and analysis is proceeding to capture the spatio-temporal patterns on a seasonal and annual basis. Information from other sources such as SeaWIFS (Chlorophyll a) will be used in an effort to determine the underlying causes of the patterns.

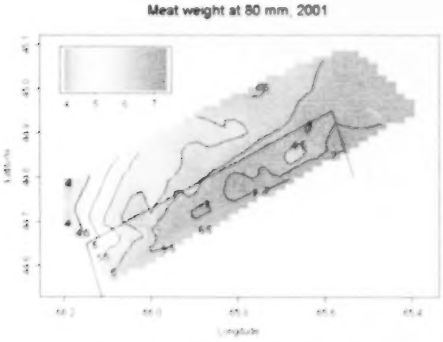


Figure 49a. Contour plot of meat weights at a shell height of 80 mm for June 2001 in the Bay of Fundy off of Digby, N.S.

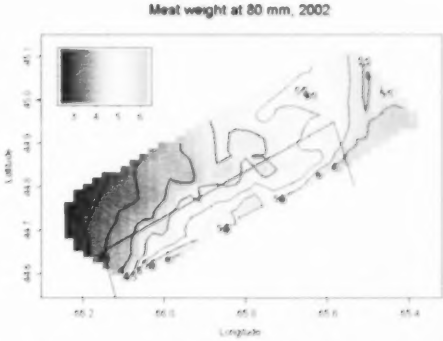


Figure 49b. Contour plot of meat weights at a shell height of 80 mm for June 2002 in the Bay of Fundy off of Digby, N.S.

4.11 Hypothesized Environmental and Evolutionary Influences on Maturation of Newfoundland Herring

C. Purchase presented a paper on this topic.

Summary

1. Maturation age (or size) is a life history trait that varies among individuals and populations within species. In fisheries, declining maturation ages can lower egg quantity and quality, increase recruitment variability, and reduce the mean size of individuals, which can lower the price per unit weight and increase fishing mortality for a constant biomass.

2. Maturation schedules can change for different reasons, which are not mutually exclusive. a) Through phenotypic plasticity maturation age often declines in response to increased growth rate (individual response). The shape of the response is often called a reaction norm and is easily reversible. b) If there is genetic variability in the predisposition to mature at a given age/size, increased mortality can result in individuals prone to mature at higher ages/sizes being less likely to survive to reproduce (versus lower ages/sizes). Therefore, maturation can evolve to a lower age (population response), which is not easily reversible.

3. Probabilistic reaction norms have been used to untangle plastic versus evolved changes in maturation age (e.g. Olsen et al. 2004). This statistical technique examines the probability of maturing at a given age and size at that age, over all ages and sizes. It assumes that age and size are the only environmental influences on maturation and that any change in the reaction norm is due to genetic change in the population.

4. Spring-spawning Newfoundland herring were assessed for temporal changes in growth and maturation from 1983 to 2005 using samples collected from standardized research gillnets.

5. There was no sexual dimorphism in maturation, and temporal trends were similar among four stocks (two on northeast coast "White Bay/Notre Dame Bay, Bonivista Bay/Trinity Bay" and two on south coast "St. Mary's Bay/Placenta Bay, Fortune Bay").

6. Age at 50% maturation declined through time (Fig. 50) and was accompanied by a reduced size at 50% maturation.

7. Growth rates decreased during the same time period (Fig. 51), a response opposite to that predicted if the decline in maturation age was due to phenotypic plasticity.

8. Somatic condition for a given age and size at that age declined through time. Therefore, "typical" probabilistic reaction norms should not be used to infer a genetic change in maturation.

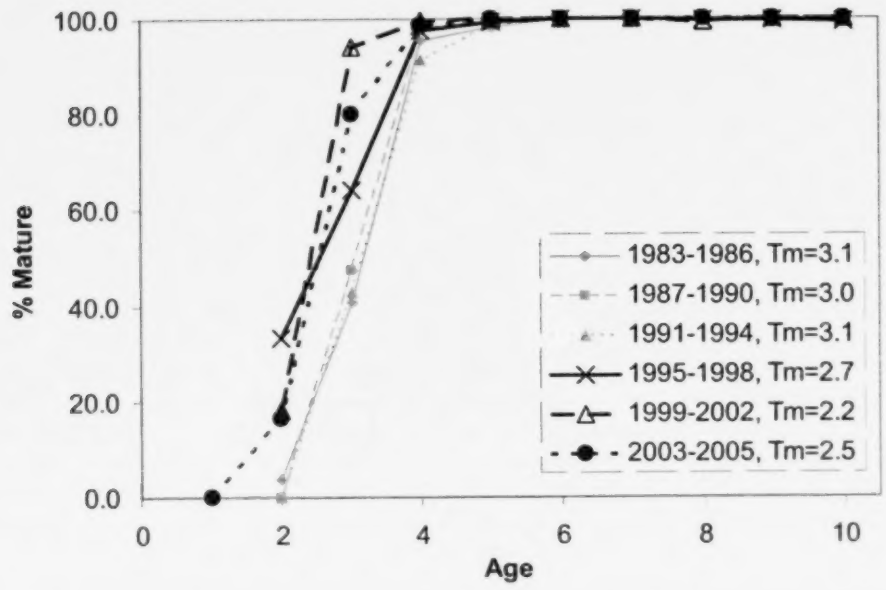


Figure 50. Maturation of Newfoundland herring, fish <22 and >37 cm have been removed in age at 50% mature Tm estimates.

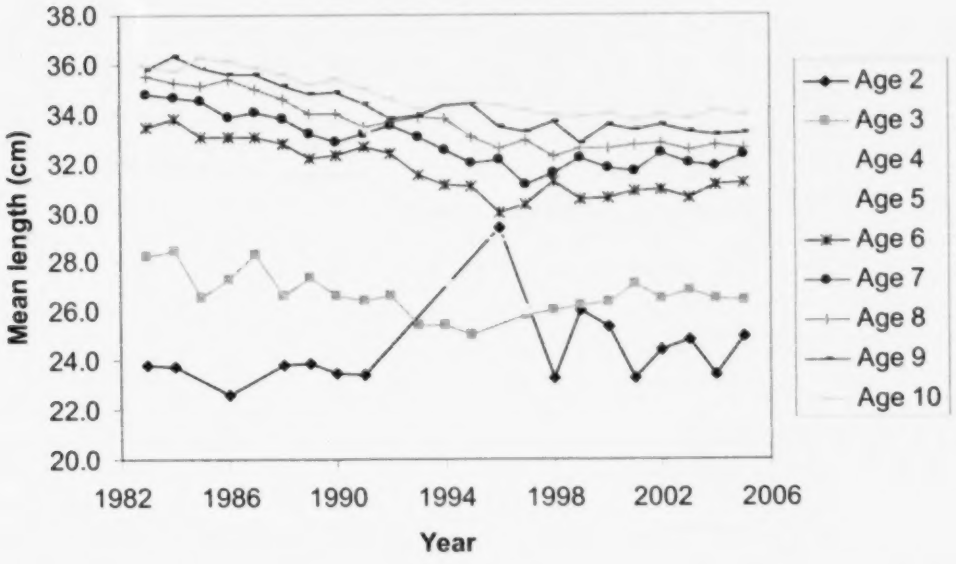


Figure 51. Size-at-age for each year. All stocks have been combined but show similar trends. Age 2 has limited sample sizes.

5.0 OTHER MATTERS

5.1 Update of "Abundance-Biomass Comparison" Plots for the Northern Gulf of St. Lawrence

C. Savenkoff presented a paper on this topic (with P. Ouellet and J.A. Gagné as co-authors).

The authors' paper updates the paper titled "Overview of Composition, Abundance, and Biomass of Fish and Invertebrates in the Northern Gulf of St. Lawrence" presented at the 2006 Fisheries Oceanography Committee meeting.

Based on the CCGS *Alfred Needler* research survey data, there was a general decrease in total fish biomass from the early 1990s to the early 2000s in the estuary (part of the NAFO Div. 4T) and the northern Gulf of St. Lawrence (NAFO divs. 4RS) (Fig. 52A). Total fish biomass excluding capelin also showed a decrease (the survey gear is considered inefficient for estimating relative capelin biomass/abundance). Four fish species (redfish, Atlantic cod, Greenland halibut, and American plaice) out of 80 accounted for 81% of the total fish biomass and 78% of total fish abundance (Fig. 52a). The overall biomass distribution of these 4 main species, all demersal, was similar to the 2 other distributions. In contrast, there was no general pattern for total fish abundance (Fig. 52b). However, when capelin was excluded, there was a decrease in total abundance for the other fish species and for the 4 main species from the early 1990s to the early 2000s (Fig. 52b). High catches of redfish juveniles in the Cabot Strait in 2005 explained the increase in the overall fish abundance distribution.

The authors produced k-dominance plots based on biomass and abundance data ("abundance-biomass comparison" plots or ABC plots) and compared them graphically. The W statistic is a measure of the difference between the abundance and dominance k-dominance curves in an ABC plot and has been used as an indicator of the level of disturbed or undisturbed conditions of the system for macrobenthic species (Clarke and Warwick 2001). Positive values represent undisturbed conditions (abundance curve below biomass curve, i.e. large-bodied species in few numbers), while negative values reflect disturbed conditions (biomass curve below abundance curve, i.e. large numbers of individuals of a few small-bodied species). The authors used all the W statistics and plotted them per year for each distribution (Fig. 53). Except for the early 1990s, the values for all species excluding capelin are positive, corresponding to "undisturbed" condition. In contrast, for the 4 main demersal species, there are only 4 positive values and they are related to the cod moratorium periods.

The temporal trend of different parameters was summarized in Fig. 54. There were general decreases in biomass and abundance of cod and redfish from the early 1990s to the early 2000s. In contrast, shrimp and seal biomass and the dispersion index of pelagic fish species (capelin and herring) increased over the same time period (Fig. 54). The dispersion index is calculated by kriging using presence and absence data of pelagic fish species gathered during bottom-trawl surveys.

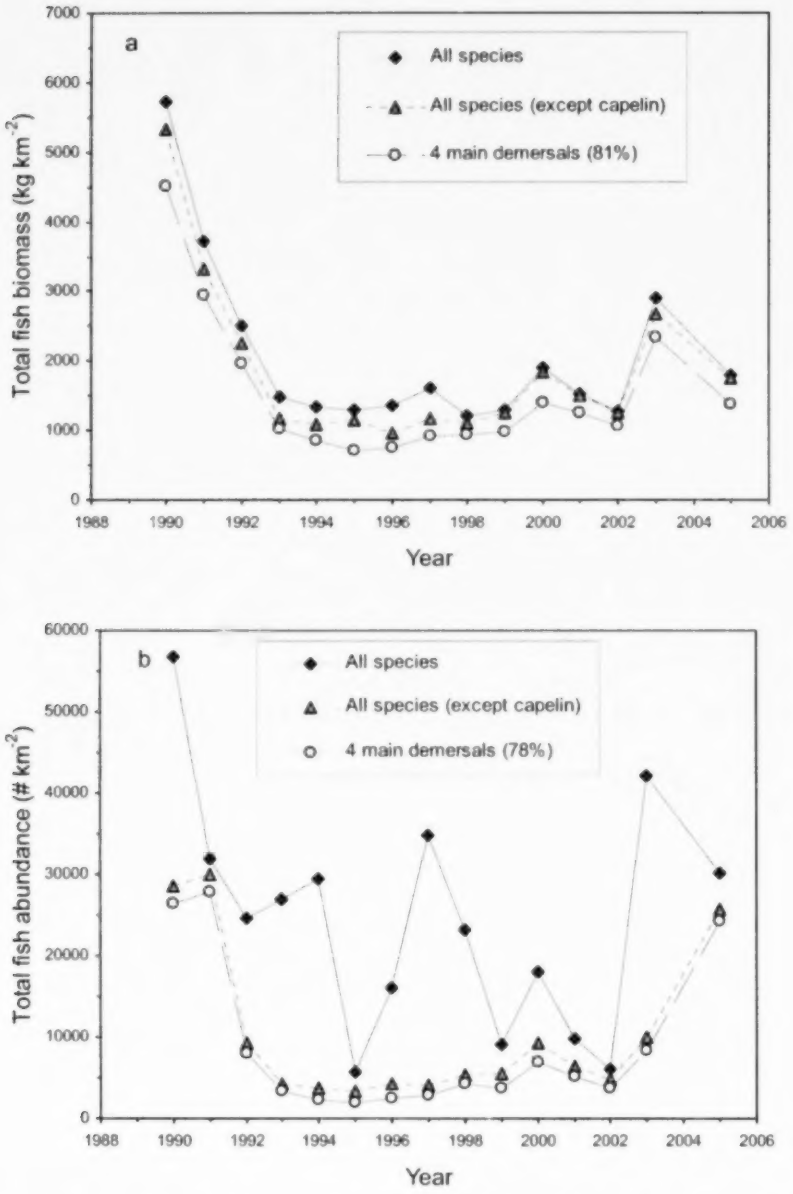


Figure 52. Total fish biomass (a) and abundance (b) based on the CCGS Alfred Needler research survey data in the estuary (part of the NAFO Div. 4T) and the northern Gulf of St. Lawrence (NAFO divs. 4RS). No survey in 2004.

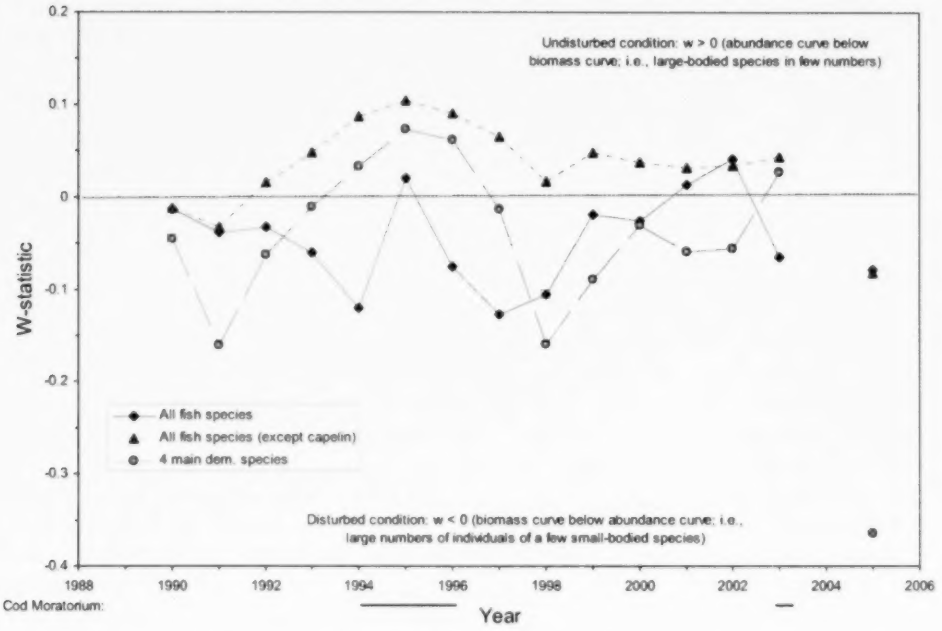

Undisturbed condition: w > 0 (abundance curve below biomass curve; i.e., large-bodied species in few numbers)
Disturbed condition: w < 0 (biomass curve below abundance curve; i.e., large numbers of individuals of a few small-bodied species)
All fish species
All fish species (except capelin)
4 main dem. species
W-statistic
Year
Cod Moratorium:

Figure 53. Temporal changes in the relative position of abundance and biomass k-dominance curves, summarized through the W statistic, for the estuary and the northern Gulf of St. Lawrence.

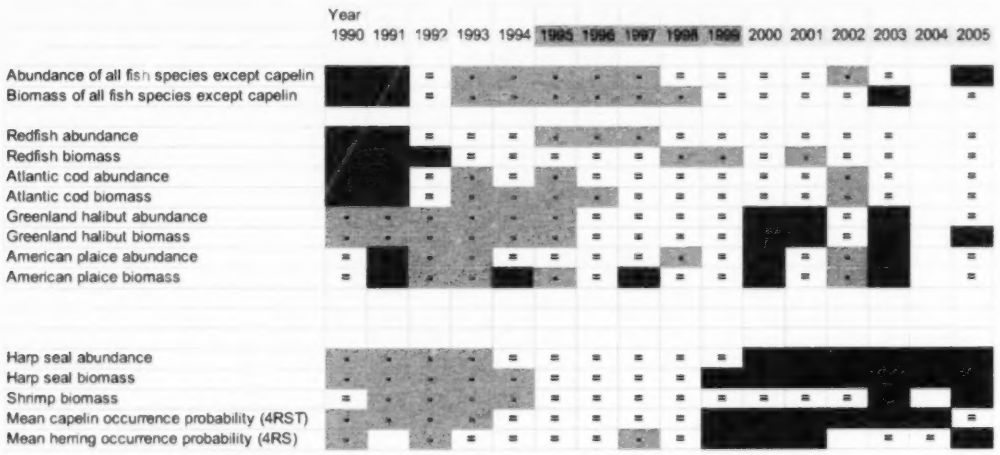

Year
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Abundance of all fish species except capelin
Biomass of all fish species except capelin
Redfish abundance
Redfish biomass
Atlantic cod abundance
Atlantic cod biomass
Greenland halibut abundance
Greenland halibut biomass
American plaice abundance
American plaice biomass
Harp seal abundance
Harp seal biomass
Shrimp biomass
Mean capelin occurrence probability (4RST)
Mean herring occurrence probability (4RS)

Figure 54. Temporal trend of different parameters. In red, the authors have the values above the upper limit of the confident interval at 95% around the overall mean (positive anomalies) and in blue, the values under the lower limit (negative anomalies).

5.2 Sharing Data with Confidence

R.M. Branton presented a paper on this topic with the following as an abstract.

Abstract

DFO Canada scientific data are a public resource that is subject to full and open access. Disciplines such as oceanography have a long tradition of data sharing. Other science disciplines like biology do not. Here the authors show techniques being develop to facilitate and manage data sharing of biological data, including: a) public discovery and access via Geoconnections, Global Change Master Directory, and Ocean Biogeographic Information System portals; b) signed data-use agreements as being employed by Population Ecology Division at the Bedford Institute of Oceanography; c) presentation of data using standardized schema and data dictionaries such as Darwin Core; d) standardized and enriched taxonomic metadata derived from the Integrated Taxonomic Information System and Food and Agriculture Organization data systems; e) summary data tables and maps produced on the DFO Maritimes Region Virtual Data Centre; and f) interoperable data products such as the Environmental Sciences Research Incorporated shape files and Open Geospatial Consortium web mapping and feature services. A survey of external data users shows that about one-half of the data access arrangements that they have undertaken included some or all of the above-noted techniques. Data publishing is now being endorsed by DFO National Science Data Management Committee. External clients are moving ahead on creation their own integrated databases. It is only a matter of time before the FOC is bypassed with regard to integrated research.

Full text of the Department of Fisheries and Oceans Canada scientific data policy can be found at: www.dfo-mpo.gc.ca/science/data-donnees/datapolicy_e.htm.

5.3 Feasibility of Developing Meaningful Abiotic and Lower Trophic Level Indices for NAFO Statistical Areas

B. Petrie presented a paper on this topic.

Hydrographic data coverage for the Labrador, Newfoundland, Gulf of St. Lawrence, Scotian Shelf, and the Gulf of Maine indicates that individual fixed-position series, area, and volumetric indexes are possible in some form for all regions. From these data, indexes of stratification and current strengths could be developed. Complementary datasets – NAO (North Atlantic Oscillation), air temperature, winds, ice cover, heat fluxes, sea level (transport estimates), SST (Sea Surface Temperature), frontal boundaries (Georges Bank to Grand Banks), eddies – could generate additional indexes.

Continuous Plankton Recorder (CPR) data provide potential indexes that can characterize the lower trophic levels, phytoplankton, and zooplankton (Fig. 55). The major drawbacks of this series are: a major gap from 1976 to 1990 in a series that began in 1961; good data coverage restricted to areas 3L, P, and 4V, W, X (see example); small opening of CPR sampler (~1 cm^2) limits larger plankton. These samples can be supplemented with *in situ* chlorophyll, though the data inventories are small for Newfoundland and the Gulf of St. Lawrence, and are spotty for the Scotian Shelf. A complete inventory of zooplankton observations was not completed for the meeting, in part because the BIOCHEM database was down for about 2 weeks. However, early queries to the database indicated that it contained 9,238 zooplankton sampling stations in Area 4x. This NAFO division and Div. 4W are likely to be the best sampled area in the zone.

Nutrient sampling has been surprisingly good for most regions with samples in most years beginning in the early 1970s. Pre-spring bloom observations would be an asset; however, sampling in February and March is generally less than in other months (see Table 8). Evaluation of oxygen data availability is highly dependent on the type of samples considered acceptable. If oxygen sensor data are useable, then the inventory of this type of data will increase substantially.

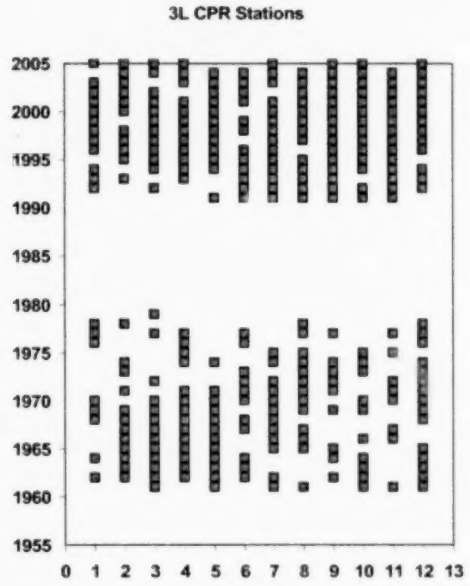


Figure 55. Distribution of CPR data in NAFO Div. 3L by month (x axis) and year.

Table 8. Distribution of nutrient samples by month in NAFO divs. 2J to 5Zw.

NAFO Area	J	F	M	A	M	J	J	A	S	O	N	D
2J		33	17		284	288	741	92		10	24	30
3K		44	31	157	342	28	572	96			207	180
3L	251	121	83	1207	998	442	1018	359	346	98	1477	449
3M				428	241	16	195		10		405	123
3N	88	118	38	556	210	122	109	101	145	185	467	3
3O	48	44	58	243	185	101	112	107	137	11	224	131
3P	38		2	280	266	204	326	89	127	315	488	117
4R	94	4	111	123	131	653	63	52	11	30	715	204
4S	395	218	291	359	233	1523	560	318	218	297	3025	1045
4T	36	51	129	102	283	1435	389	249	2291	231	764	119
4V	192	218	622	1918	816	906	1763	126	154	1420	1433	368
4W	277	358	990	2224	1035	829	2011	341	284	1193	420	128
4X	328	738	350	3178	1362	952	3430	1674	613	1519	629	860
5Y	59	518	560	1825	230	111	936	646	868	460	148	190
5Ze	55	1166	458	944	456	362	608	1268	329	264	126	892
5Zw	118	201	294	101	200	79	153	112	230	64	186	301

5.4 Review of Progress Toward Completion of Recommendations in 2006 FOC Report

The recommendations from the 2006 FOC report were:

1. A zonal review of the objectives of the regional trawl surveys is required, followed by the standardization (within surveys at least) of protocols. (Action needed by ASDC.)

2. Training is required amongst regions to ensure that minimal requirements are met (e.g. species identification).

3. Need for an outline for the regional Ecosystem Status Reports, including indices from the single-species stock assessments.

4. Identification of analyses required of AZMP in support of the comparative ecosystem analyses.

It was noted that Recommendations 1 and 2 have been taken on by ASDC, but work is still required on definition of goals of trawl surveys, protocols, and training. It was not felt that tracking the progress was a task for FOC, but that differences amongst surveys generates challenges to synthesis of data across regions.

Some progress has been made on options for an ESR outline (Recommendation 3), as discussed under Section 3.1 in this report. FOC would prefer to address the analysis and synthesis of existing data sets that are relevant to an ESR rather than define the template itself. Good progress has been made on Recommendation 4 (see Section 3.2 in this report).

6.0 GENERAL DISCUSSION

6.1 Planning for Joint Meeting with AZMP

Given the discussion under Agenda Item 1, it was agreed that an iterative approach is preferable. Rather than develop a "shopping list" of contextual oceanographic indicators of interest to "fisheries oceanography" (in relation to reporting on the "status of ecosystems"), it was felt that a joint meeting would be more constructive. At such a meeting (which could be a one-day or a half-day overlapping session with the 2 committees), the goals of the progress on synthesis of fisheries data would be summarized and alternate hypotheses on the causes of the observed changes presented. The discussion would focus on the relevant AZMP indicators to aid in the interpretation of the macro-invertebrate, fish, mammal, and seabird decadal-scale trends.

6.2 Issues and Next Steps

a) It was agreed that a workshop would be held in Moncton, New Brunswick, from February 5 to 8, 2008, to be chaired by H. Benoît. The goals of the proposed workshop are to agree on a basic set of common analyses that would be included in the various regional ESRs, and to standardize/homogenize to some degree these analyses. Choosing criteria for classifying species by functional groups, and deciding on which measures of condition should be used, are examples of "standardization/homogenization". The papers by Mathratta and Link (2006) and by Rochet and Rice (2005) would be useful for background ideas.

b) It was also proposed that a joint session be held with AZMP during the week of March 16, 2008, in Montreal, Quebec. The goal of the joint session would be to discuss the oceanographic indices that would be the most useful in the interpretation of trends in ecological and ecosystem properties at higher trophic levels. K. Frank agreed to make contact with Michel Mitchell (the Chair of AZMP) to establish the agenda for the joint session.

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ANNEX 1: TERMS OF REFERENCE

Terms of Reference

Fisheries Oceanography Committee

It is the responsibility of the Fisheries Oceanography Committee to contribute to the scientific basis for the advice on fisheries issues influenced by meteorological, oceanographic, and biological processes and interactions by:

- providing a scientific forum for the discussion of the applicatiсn and integration of environmental information and ecosystems knowledge to the analyses of the distribution and production patterns in commercially and/or ecologically important marine and diadromous species;
- reviewing pertinent scientific data and coordinating the necessary analyses to evaluate the role of environmental factors and ecosystem processes on migration, spawning time, stock definition, recruitment variability and trends, growth characteristics, and spawning stock abundance of living marine resources;
- providing a scientific forum for the integration of results and knowledge from different disciplines (e.g. ecosystem modeling, fisheries science, and biological and physical oceanography) across regions pf the northwest Atlantic to achieve a more complete understanding of changes in productivity, ecosystem structure, and availability of living marine resources to the commercial fisheries and the research surveys;
- reviewing the research requirements for fisheries oceanography and the Ecosystem Approach to Fisheries and recommending initiation of such programs to the Science Directors, as may be required; and
- maintaining a written record of the proceedings of the Committee, documenting the conclusions of the Committee and their scientific basic, and making the conclusions of the Committee available to management and the public.

ANNEX 2: AGENDA

Agenda

FOC 2007 Annual Meeting, 3–5 April, BIO
6th Floor Gully Boardroom, Polaris Building

Start: Day 1, 0900 h (coffee and lunch breaks will be factored into schedule)

Note: M. Sinclair will host a reception for FOC participants at his home on the evening of 3 April (directions will be provided).

I. Ecosystem Status Reports: Regional Needs and Content

Development of a template for regional and zonal "Ecosystem Status" reporting in support of Integrated Management under the Ecosystem Approach. (M. Sinclair, R. O'Boyle, and S. Gavaris)

General Discussion

Close encounters with AZMP – Report on integration of FOC and AZMP to produce ecosystem status reports. (K. Frank)

II. Regional Trends in Condition of Invertebrates, Fish, and Marine Mammals

Trends in the condition of marine fishes in the southern Gulf of St. Lawrence, 1971-2006. (H. Benoît)

Trends in the condition of some fish and invertebrates species/stocks in the Gulf of St. Lawrence. (P. Ouellet)

Trends in condition of Atlantic cod (*Gadus morhua*) from the southern Labrador Shelf to the Grand Banks (NAFO 2J3KLNOPs). (G. Lilly)

Changes in body condition of two pelagic species in Newfoundland waters. (F. Mowbray, J. Carscadden, and J. Wheeler)

Are there common trends in condition among fish species in the Newfoundland shelf (NAFO 2J3KLNO)? (M. Koen-Alonso, G. Lilly, J. Morgan, F. Mowbray, and D. Power)

Notes on condition of two auk species, Atlantic Puffin, and Common Murre, at Funk Island, Newfoundland. (B. Montevecchi et al., presented by M. Koen-Alonso)

A decline in body condition accompanied the increase in population size of harp and hooded seals between the 1980s and the 1990s. (D. Chabot, G. Stenson, and F.O. Kapel)

Comparative analysis of groundfish condition in 4VW and 4X from 1970-2006. (N.L. Shackell and K.T. Frank)

Condition estimates and Scotian Shelf haddock. (A. Neuheimer and C.T. Taggart)

Annual trends in meat weight/shell height relationships for sea scallop (*Placopecten magellanicus*) in the Bay of Fundy. (S.J. Smith and S. Rowe)

Hypothesized environmental and evolutionary influences on maturation of Newfoundland herring. (C. Purchase)

III. Other Important Matters

An update of k-dominance plots based on fish biomass and abundance in the northern Gulf of St. Lawrence. (C/ Savenkoff)

Sharing Data with Confidence. (R. Branton and D. Ricard)

Report of the 2007 Annual AZMP meeting. (B. Petrie)

Review of progress towards recommendations in 2006 FOC report. (M. Sinclair)

IV. Wrap-up

Planning for joint meeting with AZMP

End: Day 3, 1200 h

ANNEX 3: ATTENDANCE

Attendance

Newfoundland Region: (Northwest Atlantic Fisheries Centre)	Mariano Keon-Alonso George Lilly Fran Mowbray Craig Purchase
Québec Region: (Institut Maurice-Lamontagne)	Denis Chabot Patrick Ouellet Claude Savenkoff
Gulf Region: (Gulf Fisheries Centre)	Hugues Benoît Joel Chassé
Maritimes Region: (Bedford Institute of Oceanography and St. Andrews Biological Station)	Robert Branton Alida Bundy W. Glen Harrison Anna Neuheimer Brian Petrie Robert O'Boyle Nancy Shackell Michael Sinclair Stephen Smith Sherrylynn Rowe